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WATER POLLUTION SURVEY, BACK RIVER, 1965

Federal Water Pollution Control Administration
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Baltimore City Department of Health

Baltimore City Department of Public Works

Baltimore County Department of Health

Baltimore County Department of Public Works

Maryland State Department of Health

Maryland State Department of Water Resources

The cooperation and valuable assistance of these groups are gratefully acknowledged.

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I. CONCLUSIONS AND RECOMMENDATIONS

A field survey, designed for the purpose of determining the source, extent, and significance of bacterial pollution of the Back River Estuary, was conducted in November 1965 by the Chesapeake Field Station of the Chesapeake Bay-Susquehanna River Basins Project, in cooperation with State and local public works and health agencies. Significant water quality problems indicated by survey findings are ~~as follows:~~

1. The bacterial water quality of Back River upstream from the vicinity of Stansbury Point does not meet the Maryland State Department of Health regulations governing natural bathing areas. Coliform bacteria counts in the stream exceed the State standards, and the discharge from a large waste treatment plant in the area creates an immediate danger from potentially harmful pollution.

2. Bacterial pollution of human origin is contributed to the Back River by Herring Run and other small tributary headwater streams, and also by the Back River Sewage Treatment Plant effluent. Additional sources may exist in the Deep Creek area. The primary sources of bacterial pollution are inland and shorefront overflowing septic tanks.

3. The eutrophication of Back River is advancing rapidly, as evidenced by an extremely high algal population. Evaluation

of data indicates that a major contributor of nutrients to the River is the Back River Sewage Treatment Plant.

To minimize or eliminate these undesirable conditions, the following actions should be considered:

1. The program of elimination of inadequate private sewage disposal systems remaining in the Back River Basin should be accelerated. These sources of bacterial pollution have been identified, and priorities for extension of public sewerage were established by the Baltimore County Department of Health. Since the Summary Report of 1964, approximately 25 per cent of the inadequate systems have been, or are being, eliminated. Completion of the program is estimated to cost five million dollars.

2. The nutrient loads being contributed by the Back River Sewage Treatment Plant should be reduced, either by complete diversion of the effluent to a more suitable location or by treatment to remove nutrients.

Elimination of this rich source of nutrients would significantly decelerate the eutrophication of Back River.

As reported in the Summary Report of 1964, the Bethlehem Steel Company at Sparrows Point is continuing to use greater quantities of the Sewage Treatment Plant effluent which decreases the discharge to Back River. Complete industrial reuse of the effluent, which is presently being planned, is desirable.

II. INTRODUCTION

In the Summary Report-Pollution of Back River[1/] prepared by the Public Health Service, U. S. Department of Health, Education and Welfare, January 1964, it was concluded that the complex nature of pollution problems in the Back River Basin required that additional studies be undertaken before a Basin water quality control program was finalized.

The Chesapeake Bay-Susquehanna River Basins Project conducted a survey in November 1965 for the purpose of obtaining some of the desired information. Specifically, this survey was designed to investigate the following aspects of the problem:

1. The relative magnitude of various tributary sources of bacteriological pollution of Back River.

2. The extent of the area adversely affected by bacteriological pollution.

3. The extent to which the existing bacteriological pollution is due to human sources.

4. The dispersion and flushing which takes place in this tidal Estuary.

5. Other significant pollution problems that might exist.

This report presents the findings of the survey, an evaluation of these findings, and recommendations for corrective action to supplement the previous Summary Report.

III. THE STUDY

A. SURVEYS

Data required for the evaluation of the water quality of Back River was obtained from field surveys conducted by the Chesapeake Field Station of the Chesapeake Bay-Susquehanna River Basins Project in cooperation with State and local public works and health agencies during November 1965. The following programs were carried out:

1. Bacteriological, Physical, and Chemical Sampling and Analysis Program

Seven stations located on streams and coves tributary to Back River were sampled from ten to 20 times by personnel from the Baltimore County Department of Health and the Baltimore City Department of Health. Samples were taken from bridges both in the morning and afternoon.

Fifteen stations located in the Back River Estuary were sampled by Chesapeake Field Station personnel. Since tidewater quality indicators of primary interest could be expected to reach extreme values at the time of slack water, samples were taken at mid-depth during boat runs scheduled to coincide with the predicted time of slack water. An equal number of samples collected at times of successive slack waters should have provided good tidal average values but, due to wind effects, actual tidal times varied appreciably from predicted times, and the results must be evaluated accordingly.

The Back River Sewage Treatment Plant was also sampled by Chesapeake Field Station personnel.

A total of 368 water samples were collected for analysis of bacteriological, chemical, and physical properties.

Analyses were performed by Chesapeake Bay-Susquehanna River Basins Project personnel and by the Maryland State Department of Health laboratory personnel in Baltimore. In each case analyses were initiated within a few hours of sample collections.

The following water quality indicators were measured:

Bacteriological	
Coliform	Most Probable Number (MPN)
Fecal Coliform (FC)	Most Probable Number (MPN)
Fecal Streptococcus (FS)	Most Probable Number (MPN)
Chemical	
Oil	
Chlorides	
pH	
Chlorophyll	
Metals (Zinc, Copper, Chromium)	
Physical	
Transparency	
Total Suspended Solids	
Water Temperature	

The analytical methods used are presented in Appendix I.

2. Dye Dispersion Studies

A dye dispersion study was initiated during the survey period for the purpose of defining the mixing and transport

properties of the estuarial system. Dye was released at a constant rate into the effluent outfall sewer of the Back River Sewage Treatment Plant. Shortly after the test was started, however, the dye discharge device was destroyed by an act of vandalism, resulting in the unplanned release of la-ge amounts of dye at unknown rates and times. A subsequent repetition of this incident forced cancellation of the dye dispersion study. The small amount of data collected did not reveal any significant amount of useful information. This type of test will be repeated at a later date.

3. Nutrient Studies

Concurrently with and following the other sampling and analysis program, analysis of nutrients was made to determine the extent of phosphorus compounds in the estuarial waters and bottom sediments, nitrogen and organic carbon in the sediments, and phytoplankton in the water.

Water was sampled with a PVC Van Dorn bottle, and sediments were sampled with a two-foot Phleger cover. The observations included temperature, salinity, and Secchi disk readings. The analysis gave values for total phosphorus, phosphate, Kjeldahl nitrogen, organic carbon, and sand-silt-clay ratios.

IV. SUMMARY OF FINDINGS

A. BACTERIAL QUALITY OF BACK RIVER

The individual results of bacteriological analyses of all samples are presented in Appendix II. These results are summarized in Tables 2 and 3 where the geometric mean and standard deviation of the data from each station are given. The statistical procedures used to determine these properties are described in Appendix III. Bacterial quality of the Estuary and various tributaries is summarized as follows:

1. Back River Tributaries

Four of the five tributary streams sampled showed coliform densities greater than found at any other survey location. Moores Run (with a geometric mean coliform density (MPN) of 100,000/100 ml) was the most highly polluted location encountered in the survey. Herring Run (MPN 25,000/100 ml), Stemmers Run (MPN 21,000/100 ml), and Bread and Cheese Creek (MPN 10,000/100 ml) were the other three tributaries containing excessive coliform densities, while Redhouse Creek contained only MPN 900/100 ml.

The effluent from the Back River Sewage Treatment Plant may be considered to be a major tributary inflow to Back River. The bacterial quality of this chlorinated effluent was quite good, the mean coliform density being 90/100 ml. The coliform density of the effluent was also the most variable of any of the

locations sampled, reflecting the operational difficulties associated with maintaining a uniform chlorine residual in treatment plant effluents.

To determine relative significance of the bacterial contribution of the tributary inflows to Back River, it is necessary to consider both their bacterial densities and rate of flow. The product of these two factors gives a relative index of the total numbers of bacteria contributed per unit time by each tributary.

This procedure was carried out (Table 4) and revealed that Herring Run was the source of almost 90 per cent of both coliform and fecal coliform bacteria contributed by the five streams and the Back River Sewage Treatment Plant. Moores Run and Stemmers Run, together, provided about 10 per cent of the total, while the contributions of the Back River Sewage Treatment Plant effluent, Bread and Cheese Creek, and Redhouse Creek contributed about one per cent or less.

Analyses of samples for fecal coliform (FC) and fecal streptococci (FS) densities were performed to provide an indication of the source of the coliform bacteria observed. It has been established[2/] that a ratio of FC to FS (FC:FS) densities exceeding 2.5 at any location indicates that the coliform bacteria present are presumably of human origin. Where the FC:FS ratio is less than one, the coliform density observed is likely to

originate from animals. An intermediate ratio is considered to be inconclusive.

In each of the tributary streams the FC:FS ratio was greatly in excess of 2.5, indicating that the coliform densities were probably of human origin.

The coliforms observed in the treated sewage effluent are obviously of human origin. The FC:FS ratio (>1) was inconclusive, however, because the unexpectedly low FS density could only be expressed by an upper limit (>20/100 ml).

2. Back River Estuary

Regulations governing the bacterial quality of natural bathing beaches, adopted by the Maryland State Board of Health and Mental Hygiene, require that the average most probable number (MPN) of coliform not exceed 1,000 per 100 milliliters.

Examination of Figure 2 shows that the mean coliform density exceeds the regulatory limit in the upper three miles of the Back River Estuary or in that area upstream from Walnut Point. This conclusion is based upon the geometric mean coliform density which is often used to describe bacterial data. Consideration of the arithmetic mean density which is always higher than the geometric mean would place the limit for acceptable bathing waters slightly downstream or at Stansbury Point, as shown in Figure 3. The State regulations do not specify which mean value should be used.

The influence of polluted tributary inflows discussed previously is reflected markedly in the high bacterial levels found in the samples collected at Stations 7, 8, and C (Figure 1). These stations were located upstream from the Sewage Treatment Plant outfall, and the bacterial levels were three of the four highest found in the estuary, all being 3,000 (MPN/100 ml) or greater (See Table 2).

The highest coliform density in the estuary, 3,800 (MPN/100 ml), was at Station D in Deep Creek. Since the density at the mouth of Deep Creek, Station B, was less than half (1,600) of that found at Station D, it would appear that an additional source of bacterial pollution may exist in the vicinity of the Marilyn Avenue Bridge crossing Deep Creek. A ratio of fecal coliform to fecal streptococci of 29 at Station D suggests that the source of pollution is of human origin.

The high coliform densities found at the head of the Estuary decrease rapidly proceeding downstream (Figure 2). The geometric mean coliform density decreases to 1,000 (MPN/100 ml) near Cox Point approximately 6.3 miles above the mouth, remains the same for about one mile downstream to Walnut Point, and then diminishes steadily to a low level of 12 (MPN/100 ml) near Rocky Point (Station 1).

The fecal coliform and fecal streptococci densities follow the same trend, being highest at the head of the Estuary and dropping steadily to very low levels at the mouth. The

FC:FS ratio was never found to be less than one at any estuary location, suggesting bacterial pollution from other than human sources is not a significant factor affecting bacterial quality of Back River.

An examination of the standard deviation and the upper and lower percentile limits presented in Tables 2 and 3 reveals the variability of the coliform densities observed in the Estuary. The greatest variation in coliform density is found in the Treatment Plant effluent (J) which had a standard deviation of 1.09. The variability is also reflected in high standard deviations at Stations 5a, 5b, 6a, 6b, and 7; however, because of the downstream locations of these stations, the variability is apparently directly influenced by the Treatment Plant discharge. This variability diminishes both above and below these stations. It would appear from these data, as well as certain of the chemical data discussed below, that the Sewage Treatment Plant effluent travels along the west bank of the river for some time before being mixed throughout the entire cross-section. Further studies of water movement and circulation in the Estuary are needed to ascertain flow patterns, but the findings of this study indicate that while the Treatment Plant effluent normally contributes a small percentage of the total bacterial contamination, it will periodically cause high coliform densities, particularly on the west bank of the Estuary.

B. PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE ESTUARY

A limited amount of data on certain physical and chemical characteristics of Back River was collected. These data are summarized in Tables 5, 6, and 7.

Temperature varied slightly along the length of the Estuary within the range of 9.5 to 11.0 degrees Centigrade. The pH dropped steadily from a high value of 9.1 at the upper end of the Estuary to 7.7 at the mouth. This is a reflection of the high level of algal activity in the Estuary which diminishes as the Bay is approached. This activity is also shown by the chlorophyll levels which are highest (approximately 250 µg/l) at the head of the Estuary and drop steadily to low levels (34 µg/l) near the mouth (Figure 13).

The chlorophyll pigment levels found are among the highest ever reported in the Chesapeake Bay area. This is not unexpected, however, because of the relatively large nutrient addition by the Back River Sewage Treatment Plant effluent to the shallow Estuary. During warm weather the Estuary receives a small amount of fresh water inflow which promotes desirable flushing and exchange with the waters of the Bay. As a result, ideal conditions are created for a large increase in algal population, which is readily apparent in the green color of the Back River waters. This could ultimately cause an accumulation of unsightly and odoriferous floating mats of decaying algae along the shore.

It is interesting to note, however, that despite the existing growth stimulating conditions, Back River is virtually free of the Eurasian milfoil plant that is so prevalent in other areas of the Bay. Experiments conducted by the School of Public Health, The Johns Hopkins University (see Appendix V), in which milfoil plants were transplanted from the adjacent Middle River Estuary to Back River, seem to indicate that some quality characteristics of Back River waters are detrimental to the plant. Further study to determine these characteristics is certainly warranted.

Results of transparency measurements in Back River could also be an indicator of the high algal populations present. Transparency and chlorophyll concentrations appear to be inversely correlated; i.e., as the Bay is approached, transparency steadily improves from 10 inches to 30 inches, while chlorophyll levels decline. It is not unusual to find that high algal densities reduce the clarity of the water considerably. However, it should also be noted that the Estuary becomes deeper and contains fewer suspended solids as the Bay is approached. This factor could also have a decided influence on clarity of the water.

Observed chloride concentrations increased from about 2,400 mg/l at the head of the Estuary to almost 5,000 mg/l at the mouth, which is approximately 15 per cent of that of sea water. These high concentrations were due both to the low stream inflows normally expected in the late fall months and the extended drought

period preceding the survey. A slight lateral chloride stratification in the Estuary may be noted at Stations 5 and 6 just below the treatment plant outfall where the chloride concentration shows a slight increase from the west to the east bank. The chloride gradient is probably caused by the lower chloride concentration in the effluent discharged by the Back River Sewage Treatment Plant on the western shore, which apparently promotes a counter-clockwise horizontal circulation. Such a flow pattern would also explain the higher bacterial densities found on the western side of the Estuary.

Results of analyses for oils are inconclusive because of the low accuracy of the analytical method used at the levels encountered and the influence of sampling techniques. Samples were scooped from the water's surface where oil content should be highest. No trend in oil concentration distribution was found along the Estuary, although the levels found at Station 7 below the Eastern Boulevard Bridge were consistently higher than at any other location. The amounts of oil detected during this particular period are not considered to be excessive.

Analyses for heavy metals such as zinc, copper, and chromium were performed on water samples from each station; results are shown in Table 7. Dissolved copper and chromium were not detectable (<0.01 mg/l) while zinc concentrations of from <0.01 to a maximum of 0.08 mg/l (at Stations 8 and C) were found. These metals were readily detected in the suspended

sediment fraction of the water samples. Significantly higher particulate concentrations of each of these metals were found in samples from Herring Run, Bread and Cheese Creek, and the Back River Sewage Treatment Plant effluent. The reason for the higher concentrations at these locations could not be determined, but may be related to particular industrial activities on the drainage watersheds above the sampling points.

All of the dissolved metal concentrations observed were well below levels considered toxic to aquatic life, and the metals contents of the suspended particulate matter is of little significance in Back River.

C. EXTENT AND SOURCE OF NUTRIENTS IN THE ESTUARY

During and after the water pollution survey in November 1965, analyses of nutrients were made to determine the extent of phosphorus compounds in the estuarial water and bottom sediments, nitrogen and organic carbon in the sediments, and phytoplankton in the water. The results are plotted in Figures 8 to 14. Water was sampled with a PVC Van Dorn bottle, and sediments were sampled with a two-foot Phleger cover. The observations included temperature, salinity, and Secchi disk readings. The analyses gave values for total phosphorus, phosphate, Kjeldahl nitrogen, organic carbon, and sand-silt-clay ratios.

The profile of the river bottom and sediment depths (Figure 8) shows an estuary with a maximum water depth of ten feet

in the channel and a gradual build-up to a sill at the mouth. The sediments generally show a recent fluvial oxidized material in the upper estuary; extensive deposits showing reduced oxygen conditions extending from the Sewage Treatment Plant gradually decreasing in thickness toward the mouth of the estuary; and below this a fine, compact, gray clay of obviously different origin than the overlying material with a relatively low phosphorus content (Figure 9). The phosphorus content of both oxidized and reduced deposits (Figure 9) is similar and is in marked contrast to the low content of the underlying gray clay.

The phosphorus in the top 5 cm of bottom cores was measured and plotted (Figure 10) as representing that available for uptake into the estuary water. Organic carbon and nitrogen determinations in the same samples (Figures 11 and 12) confirm the observation that there is a rapid nutrient build-up beginning at the Sewage Treatment Plant to a maximum at Cox Point (Station 6) and a gradual reduction to values approximating conditions above the Treatment Plant effluent discharge point.

The effects of the extensive eutrophication in the Back River Estuary, accelerated by the high nutrient content of the Back River Sewage Treatment Plant effluent, are not as serious as the effects in the non-tidal body of water. The fraction of nutrient escape is large because of the shape of the Estuary and the effects of tidal excursion. This deduction is supported by

bottom core observations made during the survey which showed rapidly increased thickness of organic deposits of reduced oxygen content some distance downstream from the Treatment Plant outfall. These deposits then generally decreased in thickness approaching the Bay, presumably as the nutrient-stimulated algal growth was dispersed and diluted. Nitrogen, phosphorus, and organic carbon determinations of the sediment water interface samples also showed a rapid downstream decrease after an initial build-up below the Treatment Plant outfall. These oxidized and reduced deposits with their high available nutrient content appear to be the result of treated effluents from the Sewage Treatment Plant since it was placed in operation in 1911.

In summary, it can be concluded that eutrophication of the Back River Estuary has been accelerated by discharges from the Sewage Treatment Plant from evaluations of the following: (1) the relative position of the underlying gray clay and its relatively low phosphorus content, (2) an examination of the available nautical charts for the Back River Estuary since the 1870's, (3) the underlying gray clay sediment deposits of homogeneous, small-sized particles which are evidence of the geologic stilling basin effects of a small watershed discharging into a relatively large estuary, and (4) the increased chlorophyll formation in the lower estuary.

Present diversion of most of the Treatment Plant effluent for industrial use has probably slowed the eutrophication process. A planned further increase in the industrial use of the treated effluent may, for practical purposes, reduce nutrients to negligible levels in Back River. Land use in the Back River watershed has stabilized in urban and suburban development, so that factors other than treated waste discharges are not pertinent.

V. CORRECTIVE ACTION PROGRAM

In accordance with Federal Water Pollution Control Administration policy, all pollution studies include a program of corrective action with cost estimates, if applicable. The 1964 study suggested several areas for water quality improvement which were not evaluated because of lack of information which this study now furnishes. The original proposals to (1) control marine craft waste discharges, (2) regulate solid waste disposal areas, and (3) develop land use regulations in unsewered areas, remain valid and are provided for in continuing studies and in the new regional plan. In addition, the increase in diversion of the effluent from the Back River Sewage Treatment Plant (currently 80 per cent) to industrial water use is effective in retarding the rate of eutrophication and additional diversion should be encouraged. The cooperation of industry in increasing the degree of treatment of wastes is also desirable.

The most effective program to improve water quality in the Estuary was identified in the current study as the extension of sewerage to eliminate private disposal systems in all locations where a significant pollution problem exists and where such extensions are economically feasible.

Prior to the recent Amendment to Article 43 of the Laws of Maryland requiring all counties to provide plans for adequate sewerage systems before 1970, the Baltimore County government had

established priorities for sewer extensions by cooperation of the public works and health departments. All sources of pollution from private sewage disposal systems have been located, priorities established, some extensions completed, some are presently under construction, and the remainder are in some stage of right-of-way acquisition or design. There is some evidence of pollution in Herring Run and Moores Run within the Baltimore City limits which appears to originate as a result of deficiencies in the sewerage system. Inspectors have been assigned to locate and identify any questionable outfall discharges[3/].

It can be estimated with reasonable accuracy that 1,100 homes remain to be sewered at an estimated cost of $4.5 million, with the exceptions previously mentioned. The costs include the necessary sewage pumping stations and additional treatment plant capacity required.

The time schedule for the completion of the program is a function of the availability of funding which, in turn, depends upon State and Federal aid availability. The corrective action program then is to accelerate the sewer extension program to complete the design and make the appropriate funds available.

On March 23, 1966, the Baltimore County Planning Board adopted the Report on the Master Plan and Comprehensive Rezoning Map for the Eastern Planning Area. Part of this area includes the peninsula along the north shore of the Back River Estuary.

The schedule of development of this plan could be a significant factor in control of pollution in Back River. A proposed channel, as part of the development of port facilities, could be quite effective in increasing the amount of tidal excursion, the resulting dilution of nutrients, and the lowering of water temperatures. The beneficial water quality aspects of a deepened shipping channel is directly related to the concurrent development of pollution control facilities in the area and correction of existing inadequacies.

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3. "Physical Condition of Streams in Baltimore," Ira L. Whitman, December 1966, prepared for Baltimore (City) Department of Public Works.

TABLE 1

DESCRIPTION OF SAMPLING STATIONS

Designation	Stream	River Mile	Description
	(Chesapeake Field Station Stations)		
1	Back River	0.00	Midstream, at river mouth, between Rocky Point and Drum Point.
2	Back River	1.69	Midstream, between Claybank Point and unnamed point on western shore.
3	Back River	3.11	Midstream, between Porter Point and Todd Point.
4	Back River	4.39	Midstream, opposite Stansbury Point.
5a	Back River	5.37	Near western shore, opposite Walnut Point.
5b	Back River	5.37	Midstream, opposite Walnut Point.
5c	Back River	5.37	Near eastern shore, opposite Walnut Point.
6a	Back River	6.32	Near western shore, opposite Cox Point.
6b	Back River	6.32	Midstream, opposite Cox Point.
6c	Back River	6.32	Near eastern shore, opposite Cox Point.
7	Back River	7.65	Midstream, at Eastern Boulevard Bridge.
8	Back River	8.00	Midstream, opposite unnamed point at confluence of Back River and Northeast Creek.
A	Muddy Gut (tidal)	4.90	Midstream, at mouth.

TABLE 1 (Continued

Designation	Stream	River Mile	Description
B	Deep Creek (tidal)	6.30	Midstream, near mouth, between two unnamed points.
C	Northeast Creek (tidal)	8.00	Midstream, about 0.2 mile above mouth.
D	Deep Creek (tidal)	6.30	Midstream, about 0.2 mile above Marilyn Avenue Bridge.
E	Stemmers Run (non-tidal)	8.00	At bridge, on Stemmers Run Road (continues as Back River Neck Road).
F	Redhouse Creek (non-tidal)	9.20	At bridge, on U. S. 40.
G	Moores Run	10.20	At bridge, on U. S. 40.
H	Herring Run	9.20	At bridge, on U. S. 40.
I	Bread and Cheese Creek	6.90	At bridge, on North Point Boulevard.
J	Sewage Treatment Plant Effluent	6.76	After chlorine contact chamber.
	(Sewage Treatment Plant Boat Stations)		
B-1	Back River	7.11	Midstream, opposite Greenmarsh Point.
B-1-A	Back River	6.78	At Sewage Treatment Plant Effluent discharge.
B-1-B	Back River	6.29	Midstream, opposite Cox Point.
B-2	Back River	4.91	Midstream, about 0.2 mile downstream from Walnut Point.
B-3	Back River	3.12	Midstream between Porter Point and Todd Point.

TABLE 1 (Continued)

Designation	Stream	River Mile	Description
B-4	Back River	1.70	Midstream, between Claybank Point and unnamed point on western shore.
B-5	Back River	0.00	Midstream, at river mouth between Rocky Point and Drum Point.
B-6	Chesapeake Bay	-1.60	Midway between Wells Point and Millers Island.
B-7	Chesapeake Bay	-3.53	About 1.5 mile northeast of Millers Island and 2.2 mile east of Wells Point--Booby Bar headland.
	(Sewage Treatment Plant Shore Stations)		
S-1	Back River	7.12	From western shore at Greenmarsh Point.
S-2	Back River	7.65	At southwestern end of Eastern Boulevard Bridge.
S-4	Back River	7.65	At northeastern end of Eastern Boulevard Bridge.
S-5	Back River	6.14	From eastern shore at foot of Scandalwood Road, about 0.1 mile southeast of mouth of Deep Creek.
S-7	Back River	6.28	From eastern shore at foot of Riverside Drive about 0.1 mile northwest of Cox Point.
Spillway Within Sewage Treatment Plant		---	Point at which flow is diverted to Bethlehem Steel Company Plant.

TABLE 1 (Continued)

Designation	Stream	River Mile	Description
Thiosulfate Contact Tank, Sewage Treatment Plant Effluent		6.76	After chlorine contact chamber, samples treated with thiosulfate to inhibit chlorine.

TABLE 2

CFS BACK RIVER SURVEY, November 1-12, 1965

SUMMARY OF COLIFORM DENSITIES

Station	No. of Samples	Arith. Mean[a] MPN/100 ml	Geometric Mean[b] MPN/100 ml	Geometric Std. Dev. a/	Percentile Limits 95% MPN/100 ml	Percentile Limits 5% MPN/100 ml
1	12	22	12	.23	28	5.0
2	12	270	48	.56	400	6.0
3	12	270	170	.17	320	90
4	20	860	400	.29	1,200	130
5a	20	3,700	1,200	.40	5,400	260
5b	20	2,200	1,000	.29	3,000	330
5c	20	600	420	.12	670	260
6a	19	12,000	2,100	.57	18,000	240
6b	22	3,400	960	.44	5,000	180
6c	20	2,300	1,300	.21	2,900	610
7	20	13,000	3,500	.46	20,000	610
8	20	6,000	3,200	.24	8,000	1,300
A	20	1,400	440	.39	1,900	100
B	18	3,700	1,600	.32	5,400	470
C	19	4,900	3,000	.18	5,900	1,500
D	10	11,000	3,800	.38	16,000	890
E	13	48,000	21,000	.31	67,000	660
F	13	5,100	900	.56	6,900	120
G	13	200,000	100,000	.26	280,000	39,000
H	13	60,000	25,000	.33	88,000	7,100
I	12	20,000	10,000	.26	27,000	3,700
J	20	10,000	90	1.09	5,400	1.5

a/ Computed by Thomas' relation. See Appendix III.

b/ Expressed as a logarithm. Variability of the 5-tube MPN test eliminated by subtracting 0.25.

TABLE 3

CFS BACK RIVER SURVEY, November 1-12, 1965

SUMMARY OF FECAL COLIFORM AND FECAL STREPTOCOCCUS DENSITIES

Station	FECAL COLIFORM No. of Samples	Mean* MPN/100 ml	Std. Dev. a/	FECAL STREPTOCOCCI No. of Samples	Mean* MPN/100 ml	Std. Dev. a/	Ratio: Fecal Coli. / Fecal Strep.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	12	<20	--	10	<20	--	--
2	12	12	.89	10	<20	--	>.6
3	12	37	.73	10	<20	--	>1.8
4	20	56	.55	20	<20	--	>2.8
5a	20	140	1.00	20	10	.80	14
5b	20	130	.98	20	5.4	1.18	24
5c	20	150	.99	20	9.1	.92	16
6a	19	630	.97	20	28	1.05	22
6b	22	280	.82	20	27	.80	10
6c	19	200	.95	20	24	.72	8
7	19	320	1.00	20	37	.82	9
8	19	530	.46	20	52	.43	10
A	20	140	.80	20	<20	--	>7
B	18	280	.87	18	35	.91	8
C	18	350	.65	18	13	1.17	27
D	10	550	.63	10	19	.63	29
E	13	1,100	.55	4	115	1.00	10
F	13	160	.48	4	<30	--	5
G	13	16,000	.95	4	140	.70	114
H	13	3,800	.53	4	105	1.28	36
I	12	1,400	.52	3	32	.49	44
J	20	23	1.30	20	<20	--	>1

* Geometric Mean.

a/ Standard deviation is expressed in logarithmic units. No correction was applied.

TABLE 4

CFS BACK RIVER SURVEY, November 1-12, 1965

BACTERIAL CONTRIBUTIONS BY VARIOUS SOURCES

(1)	Station (2)	Mean Flow, cfs a/ (3)	MEAN* DENSITY Coliforms (4) MPN/100 ml.	MEAN* DENSITY Fecal Coliforms (5)	RELATIVE FLOW RATES Coliforms (3) x (4) (6)	Coliforms % of Total (7)	Fecal Coliforms (3) x (5) (8)	Fecal Coliforms % of Total (9)
E	Stemmers Run	1.18	18,000	1,100	21.2×10^3	3.8	12.9×10^2	1.3
F	Redhouse Creek	0.28	760	160	$.21 \times 10^3$	0.0	$.45 \times 10^2$	0.0
G	Moores Run	0.47	85,000	16,000	40.0×10^3	7.3	75.2×10^2	7.7
H	Herring Run	23.0	21,000	3,800	483×10^3	87.7	874×10^2	89.4
I	Bread and Cheese Creek	0.30	8,500	1,400	2.55×10^3	.5	4.2×10^2	0.4
J	STP Effluent	49.3	80	23	3.94×10^3	.7	11.3×10^2	1.2
					550.9×10^3	100.0	978.0×10^2	100.0

* Geometric mean.

a/ Flow assumed constant throughout survey. Streams in this region were in steady flow condition during the study period.

TABLE 5

CFS BACK RIVER SURVEY, November 1-12, 1965

SUMMARY OF PHYSICAL DATA

Station	Light Extinction Depth by Secchi Disc		Total Susp. Solids		Water Temperature	
	Median Value inches	No. of Samples	Mean Conc. mg/l	No. of Samples	Median Value °C	No. of Samples
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	30	10	38	1	10.0	10
2	23	10	46	1	9.5	10
3	15	10	67	1	9.5	10
4	12	20	400	2	10.5	20
5a	11	19	220	2	10.5	20
5b	10	19	130	2	10.4	20
5c	11	19	1,900	2	10.5	19
6a	10	19	160	2	11.0	20
6b	11	19	71	2	11.0	20
6c	11	18	92	2	10.9	20
7	10	19	84	2	10.8	20
8	10	19	150	1	10.5	20
A	12	18	290	2	10.4	20
B	10	17	110	2	10.6	18
C	9	18	44	1	10.6	19
D	--	--	94	1	--	--
E	--	--	--	-	--	--
F	--	--	--	-	--	--
G	--	--	--	-	--	--
H	--	--	4	1	--	--
I	--	--	5	1	--	--
J	--	--	66	2	--	--

TABLE 6

CFS BACK RIVER SURVEY, November 1-12, 1965

SUMMARY OF CHEMICAL DATA (EXCEPT METALS)

Station	pH		Chlorides		Oil		Chlorophyll	
	Mean* Value	No. of Samples	Median Conc. mg/l	No. of Samples	Mean Conc. mg/l	No. of Samples	Mean Conc. µg/l	No. of Samples
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	7.7	2	4,950	10	6	1	34	1
2	8.0	2	4,840	10	4	1	92	1
3	8.1	2	4,230	10	6	1	140	1
4	8.3	4	3,810	20	2	4	160	1
5a	8.5	4	3,290	20	4	4	200	1
5b	8.6	4	3,360	20	6	4	200	1
5c	8.7	4	3,390	20	6	4	230	1
6a	8.7	4	2,600	20	8	4	190	1
6b	8.7	4	2,720	20	7	4	180	1
6c	8.7	4	2,750	20	5	4	240	1
7	9.0	4	2,440	20	9	4	260	1
8	9.1	4	2,380	20	4	3	250	1
A	8.3	4	3,740	20	7	4	280	1
B	8.8	4	3,180	18	6	4	250	1
C	9.1	3	2,310	19	4	3	180	1
D	8.7	2	2,900	10	-	-	--	-
E	--	-	24	4	-	-	--	-
F	7.6	1	18	4	-	-	--	-
G	--	-	44	4	-	-	--	-
H	--	-	65	4	-	-	--	-
I	7.2	1	33	3	-	-	--	-
J	7.1	4	120	20	-	-	--	-

* Geometric Mean

TABLE 7

CFS BACK RIVER SURVEY, November 5, 1965*

HEAVY METALS CONCENTRATIONS

Station	Zinc[a] Soluble mg/l	Zinc[a] Particulate mg/g[b]	Copper[a] Soluble mg/l	Copper[a] Particulate mg/g[b]	Chromium[a] Soluble mg/l	Chromium[a] Particulate mg/g[b]
1	0.02	2.6	<0.01	4.2	<0.01	1.0
2	0.03	1.3	<0.01	1.5	<0.01	0.43
3	0.01	2.1	<0.01	1.6	<0.01	3.7
4	0.01	0.94	<0.01	0.63	<0.01	0.78
	0.06	1.0	<0.01	0.32	<0.01	1.9
5a	0.01	1.4	<0.01	0.06	<0.01	1.3
	0.05	0.93	<0.01	0.04	<0.01	1.2
5b	0.01	2.9	<0.01	0.69	<0.01	0.98
	<0.01	1.5	<0.01	0.06	<0.01	1.8
5c	0.05	1.4	<0.01	0.40	<0.01	1.7
	<0.01	0.6	<0.01	0.16	<0.01	0.50
6a	0.03	2.1	<0.01	1.1	<0.01	2.5
	0.05	1.1	<0.01	0.43	<0.01	1.3
6b	<0.01	7.2	<0.01	3.1	<0.01	6.7
	0.02	1.9	<0.01	1.2	<0.01	9.3
6c	<0.01	2.7	<0.01	2.0	<0.01	4.0
	0.01	2.2	<0.01	0.95	<0.01	7.6
7	<0.01	2.0	<0.01	1.4	<0.01	5.2
	<0.01	1.6	<0.01	0.68	<0.01	7.8
8	0.08	1.7	<0.01	0.94	<0.01	1.7
A	0.06	1.2	<0.01	0.56	<0.01	1.3
	0.06	1.4	<0.01	0.57	<0.01	2.8
B	0.03	1.9	<0.01	1.5	<0.01	2.4
	0.04	1.8	<0.01	1.3	<0.01	1.6
C	0.08	4.3	<0.01	3.2	<0.01	4.3
D	<0.01	1.7	<0.01	0.95	<0.01	2.8
H	0.03	34	<0.01	24	<0.01	16
I	<0.01	36	<0.01	19	<0.01	13
J	0.04	14	<0.01	7.5	<0.01	2.7
	0.03	1.6	<0.01	0.8	<0.01	2.2

* All samples were taken on November 5.

a/ Expressed as weight of metal regardless of valence.

b/ Milligrams per gram of suspended solids.

TABLE 8

BACK RIVER, 1962 - 1965

SUMMARY OF COLIFORM DENSITIES[a] AT BALTIMORE
BACK RIVER SEWAGE TREATMENT PLANT SHORE STATIONS

May - September 1962

Station (1)	No. of Samples (2)	Mean* MPN/100 ml (3)	Standard Deviation* [b] (4)	Percentile Limits 95% (5)	5% (6)
S-1	20	3,800	0.52	27,000	540
S-2	20	1,700	0.64	19,000	150
S-4	20	4,300	0.50	28,000	650
S-5	20	1,200	0.51	8,300	170
S-7	20	4,100	0.43	21,000	800
Spillway	20	2.1×10^6	0.36	8.2×10^6	540,000
TCT[c]	18	4,100	0.67	52,000	330

May - September 1963

Station (1)	No. of Samples (2)	Mean* MPN/100 ml (3)	Standard Deviation* [b] (4)	Percentile Limits 95% (5)	5% (6)
S-1	13	2,800	0.57	24,000	330
S-2	16	1,100	0.78	21,000	58
S-4	16	1,700	0.63	18,000	160
S-5	16	1,200	0.48	7,400	190
S-7	16	2,800	0.48	17,000	450
Spillway	16	6.1×10^6	0.26	16×10^6	2.3×10^6
TCT[c]	16	1,700	0.70	24,000	120

* Geometric

[a] By Presumptive Test using 3 tubes per dilution.

[b] Corrected to eliminate variability in MPN test; reported in log units.

[c] Samples treated with thiosulfate to inhibit chlorine.

TABLE 8 (Continued)

BACK RIVER, 1962 - 1965

SUMMARY OF COLIFORM DENSITIES[a] AT BALTIMORE
BACK RIVER SEWAGE TREATMENT PLANT SHORE STATIONS

June - October 1964

Station (1)	No. of Samples (2)	Mean* MPN/100 ml (3)	Standard Deviation* [b] (4)	Percentile Limits 95% (5)	5% (6)
S-1	12	2,400	0.61	24,000	240
S-2	18	4,900	0.88	13,000	1,800
S-4	18	1,000	0.02	10,000	95
S-5	17	2,800	0.56	23,000	340
S-7	17	1,400	0.65	16,000	120
Spillway	18	7.6×10^6	0.09	11×10^6	5.4×10^6
TCT[c]	17	1,000	0.95	36,000	28

May - September 1965

Station (1)	No. of Samples (2)	Mean* MPN/100 ml (3)	Standard Deviation* [b] (4)	Percentile Limits 95% (5)	5% (6)
S-1	14	3,400	0.30	11,000	1,100
S-2	14	9,100	0.88	250,000	330
S-4	14	2,200	0.86	56,000	86
S-5	14	910	0.41	4,300	190
S-7	14	1,400	0.62	15,000	130
Spillway	14	7.6×10^6	0.20	16×10^6	3.6×10^6
TCT[c]	14	2,700	0.84	65,000	110

* Geometric

[a] By Presumptive Test using 3 tubes per dilution.

[b] Corrected to eliminate variability in MPN test; reported in log units.

[c] Samples treated with thiosulfate to inhibit chlorine.

TABLE 9

BACK RIVER, 1962 - 1965

SUMMARY OF COLIFORM DENSITIES AT BALTIMORE
SEWAGE TREATMENT PLANT BOAT STATIONS

Station	No. of Samples	Geometric Mean MPN/100 ml	Geometric Std.Dev.[a/]	Percentile Limits 95% MPN/100 ml	Percentile Limits 5% MPN/100 ml
B-1	14	1,400	0.58	12,000	160
B-1-A	13	1,400	0.70	20,000	99
B-1-B	14	1,700	1.57	63,000	46
B-2	14	91	0.60	870	9.5
B-3	14	45	0.21	98	21
B-4	14	44	0.38	180	11
B-5	14	32	0.54	250	4.1
B-6	14	18	0.83	410	0.79
B-7	13	13	0.52	92	1.8

[a/] Expressed as a logarithm. Variability of the 3-tube MPN test eliminated by subtracting 0.32.

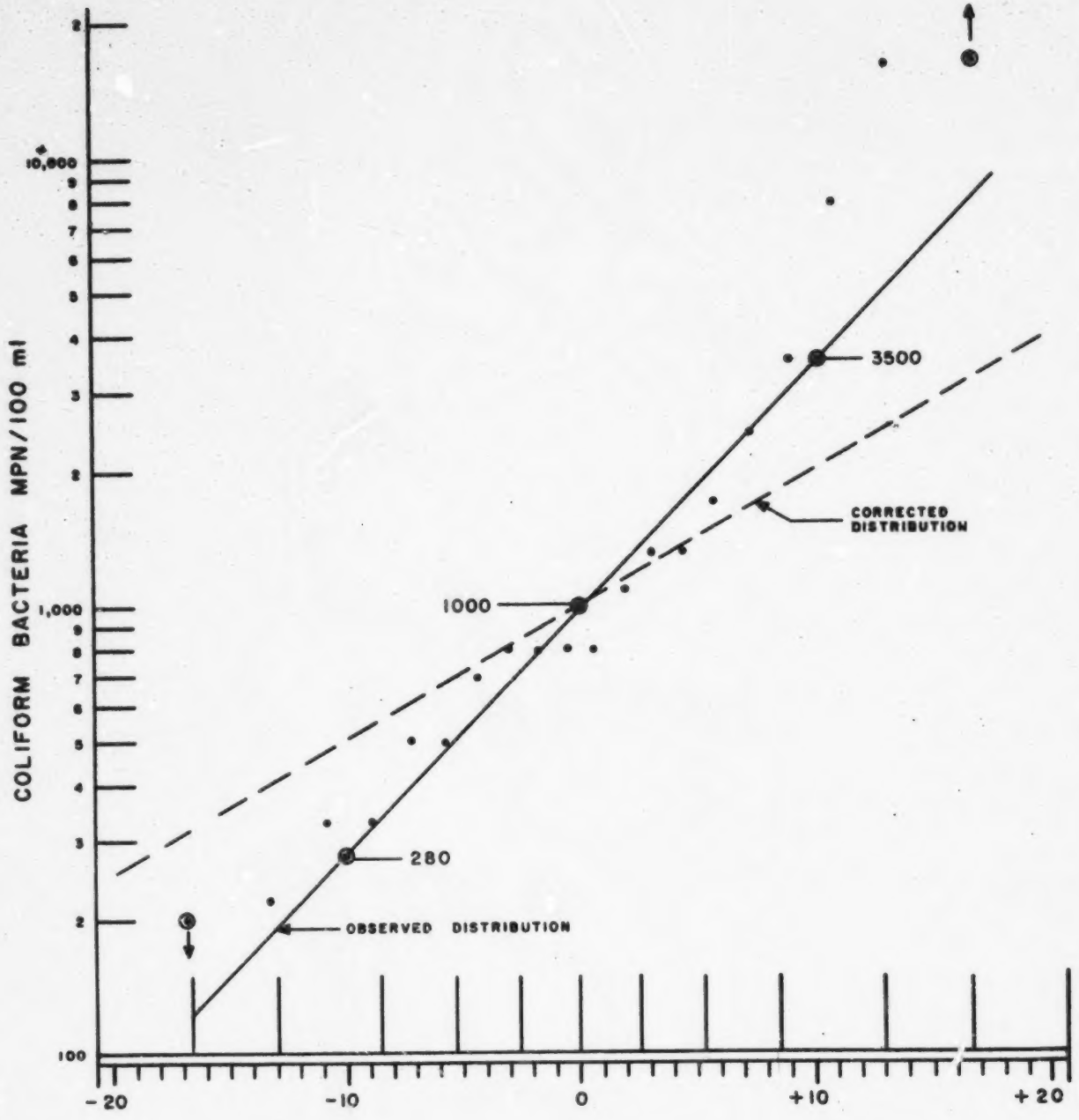
Samples collected June through September of each year and analyzed using the presumptive test with 3 tubes per serial dilution.

TABLE 10

BACK RIVER BASIN

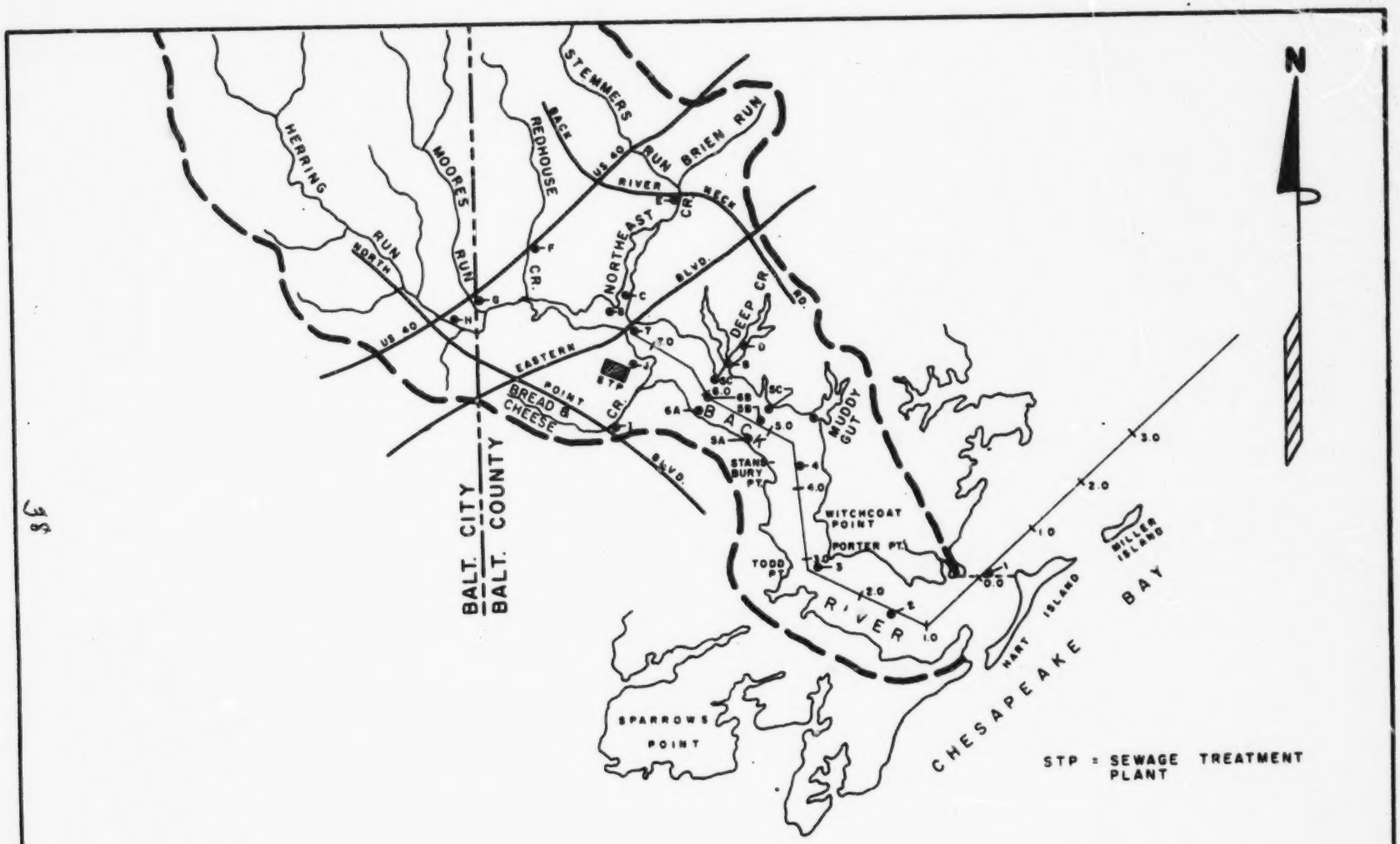
CAPACITIES OF SEWAGE PUMPING STATIONS

Pumping Station No.	Operated by	Capacity gpm
1	Baltimore City	360
2	Baltimore City	1,600
3	Private	Unknown
4	Private	1,800
5	Baltimore City	1,000
6	Private	1,450
7	Private	Unknown
8	Private	545
9	Baltimore City	70
10	Baltimore City	200
Unnumbered	Baltimore City	Unknown



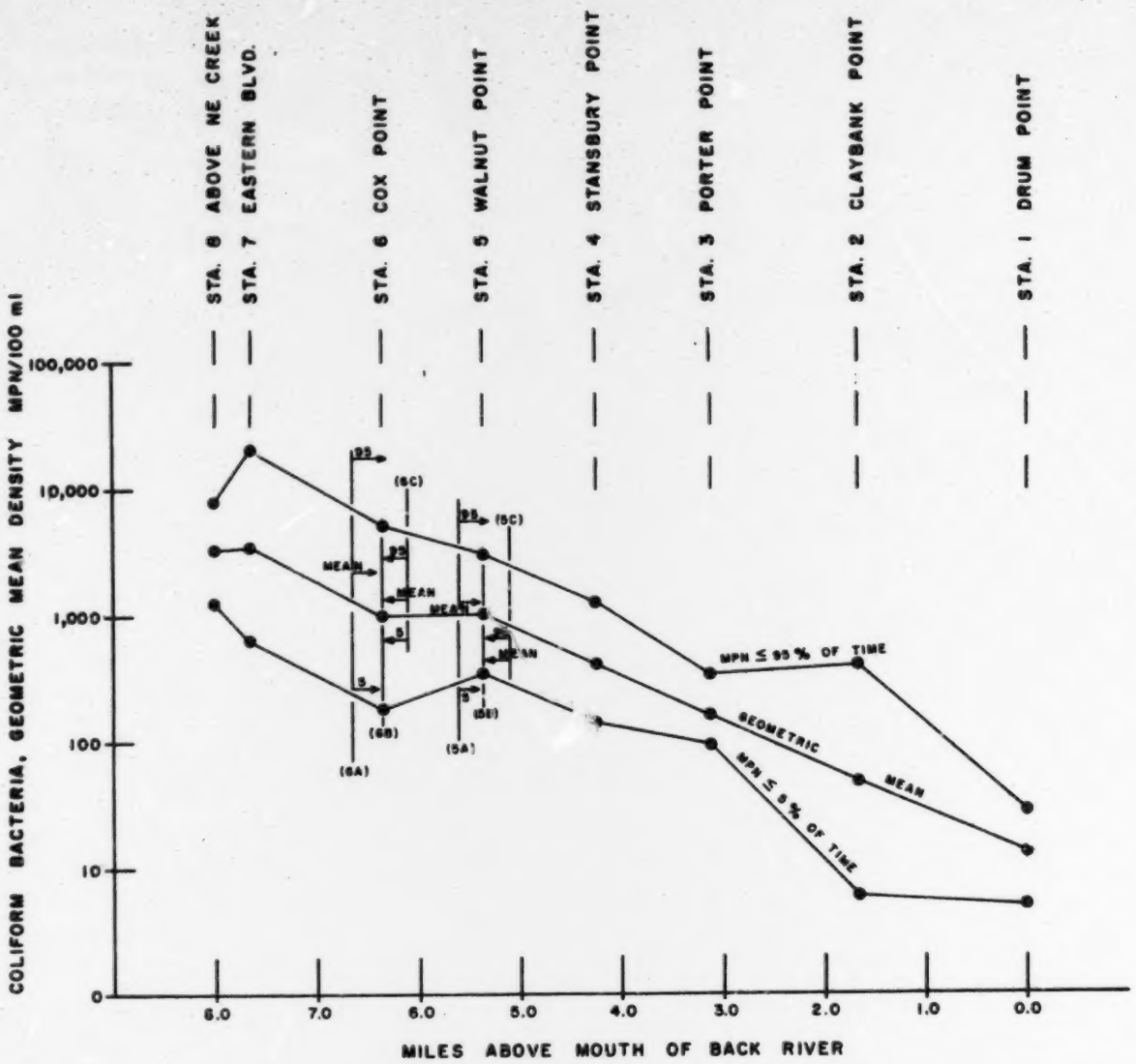
SAMPLE PROBABILITY PLOT

FIGURE A-1



BACK RIVER BASIN
LOCATION OF
CFS SAMPLING STATIONS

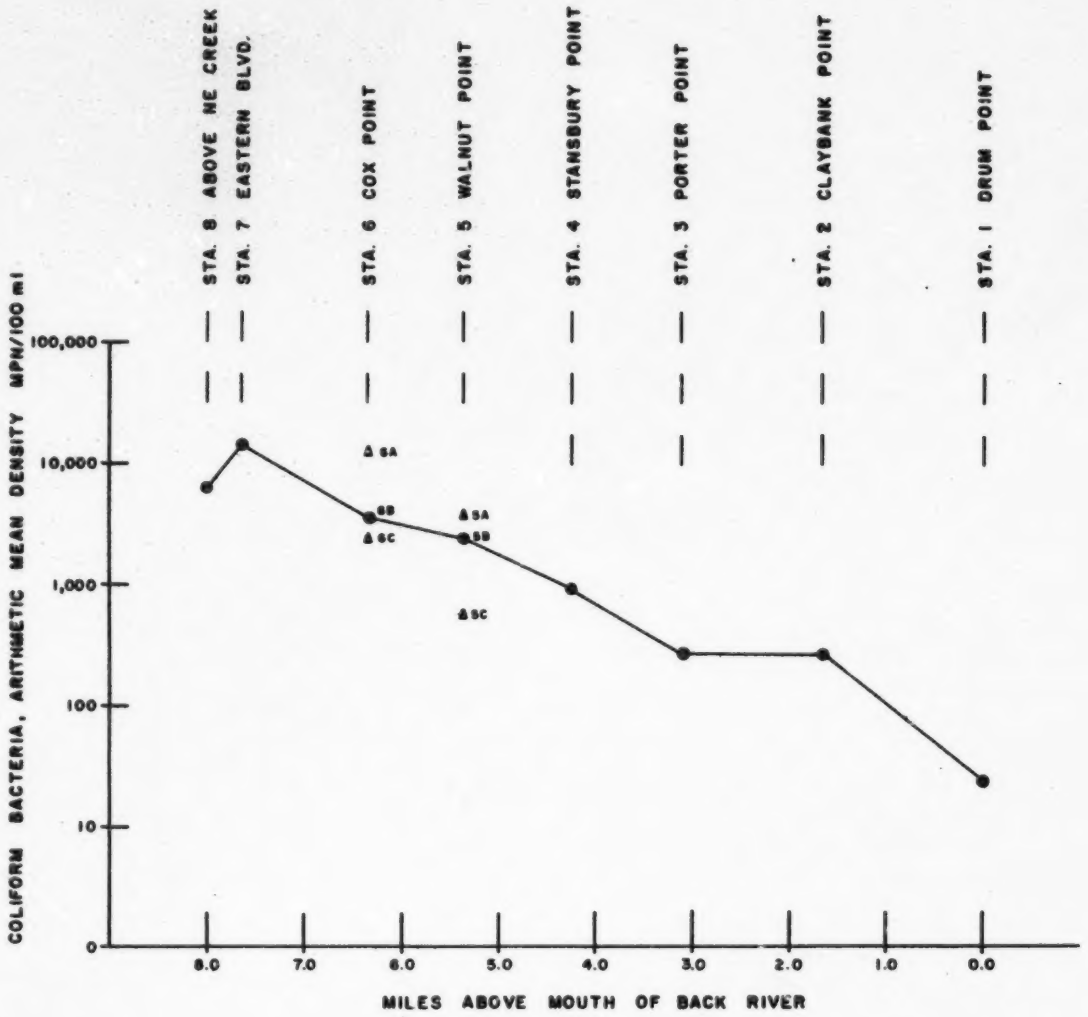
FIGURE 1



BACK RIVER ESTUARY

PROFILE OF RIVER COLIFORMS, GEOMETRIC MEANS, CFS

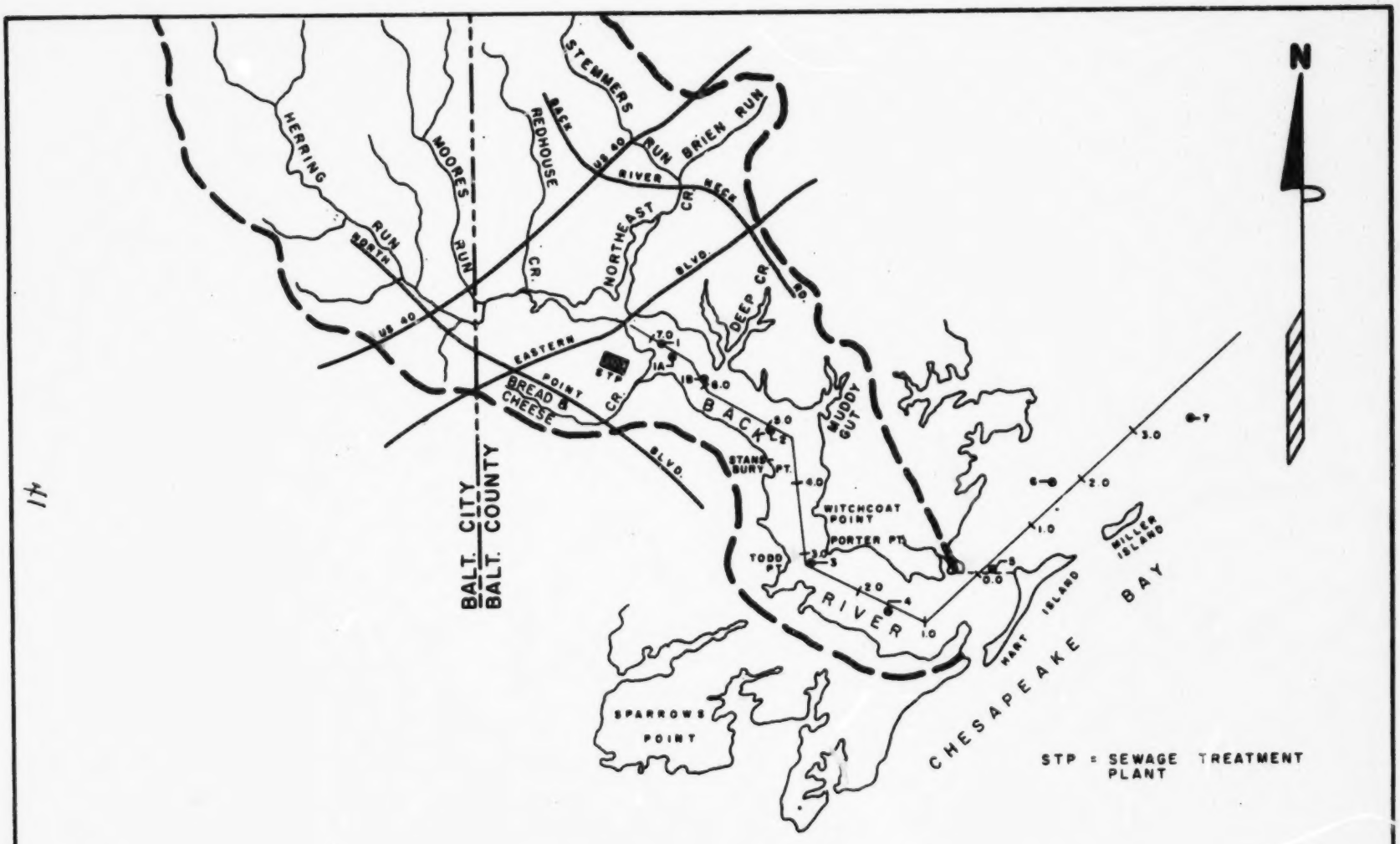
FIGURE 2



BACK RIVER ESTUARY

PROFILE OF RIVER COLIFORMS, ARITHMETIC MEANS, CFS

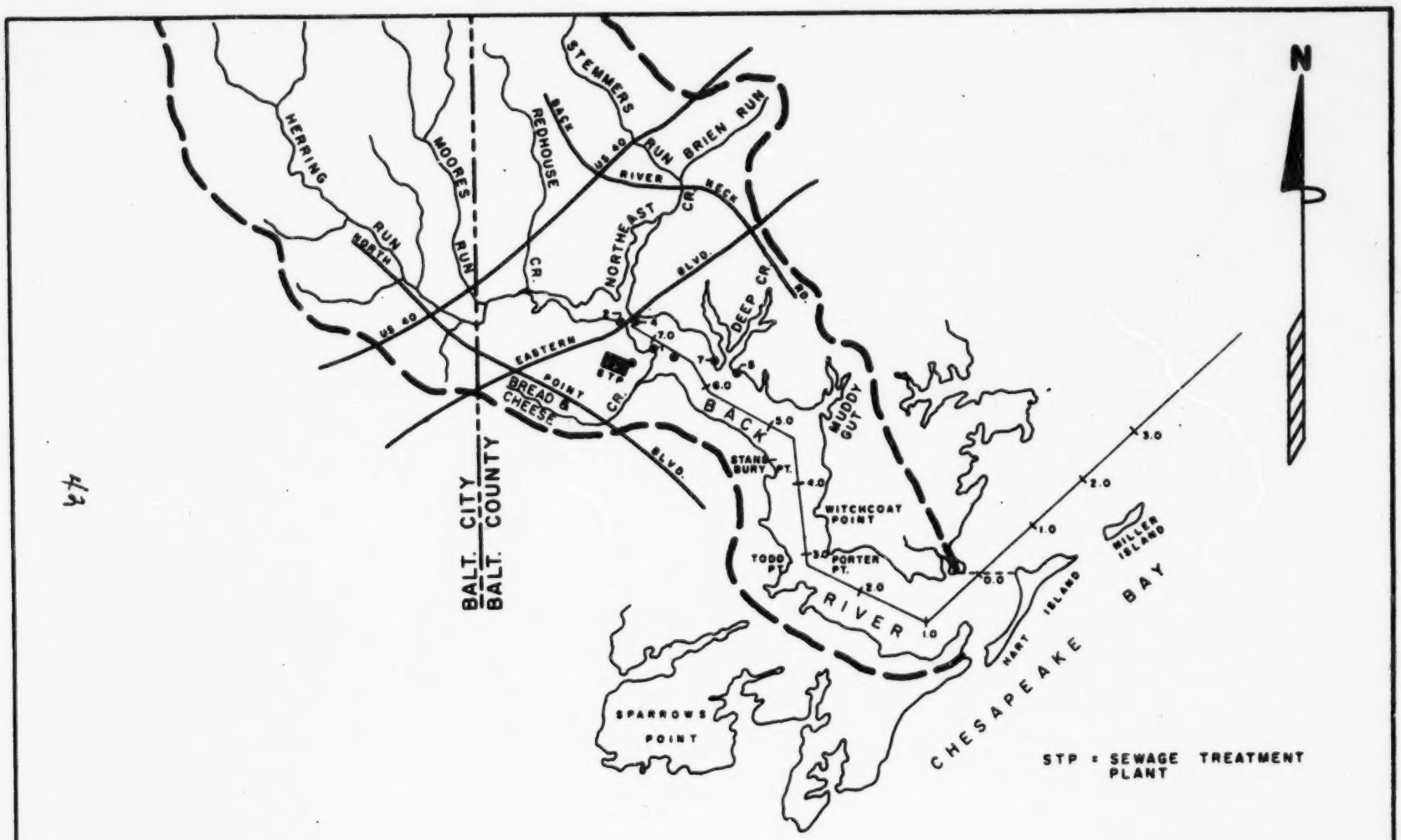
FIGURE 3



BACK RIVER BASIN

LOCATION OF BALTIMORE BACK RIVER STP BOAT STATIONS

FIGURE 4



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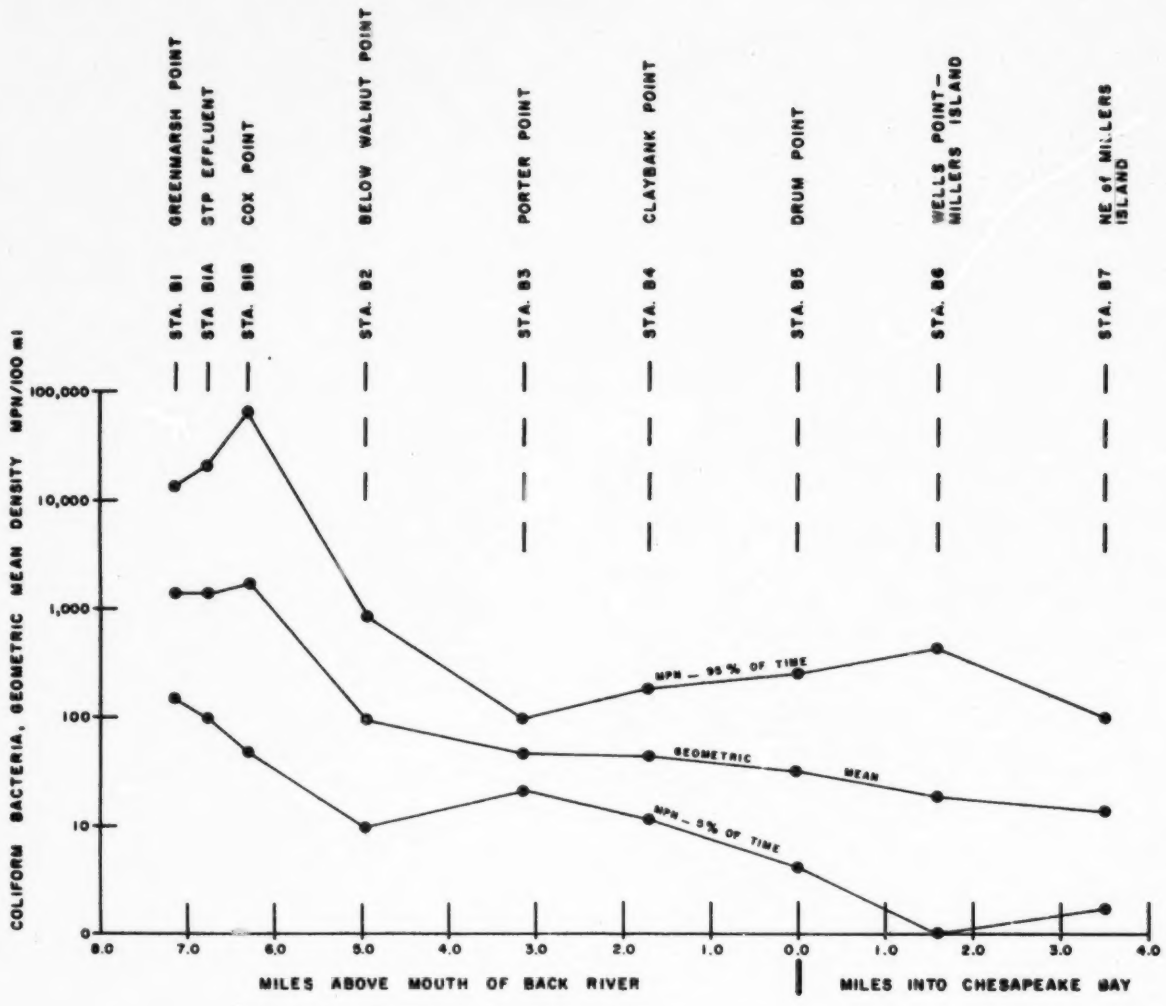
BACK RIVER BASIN

LOCATION OF

BALTIMORE BACK RIVER STP SHORE STATIONS

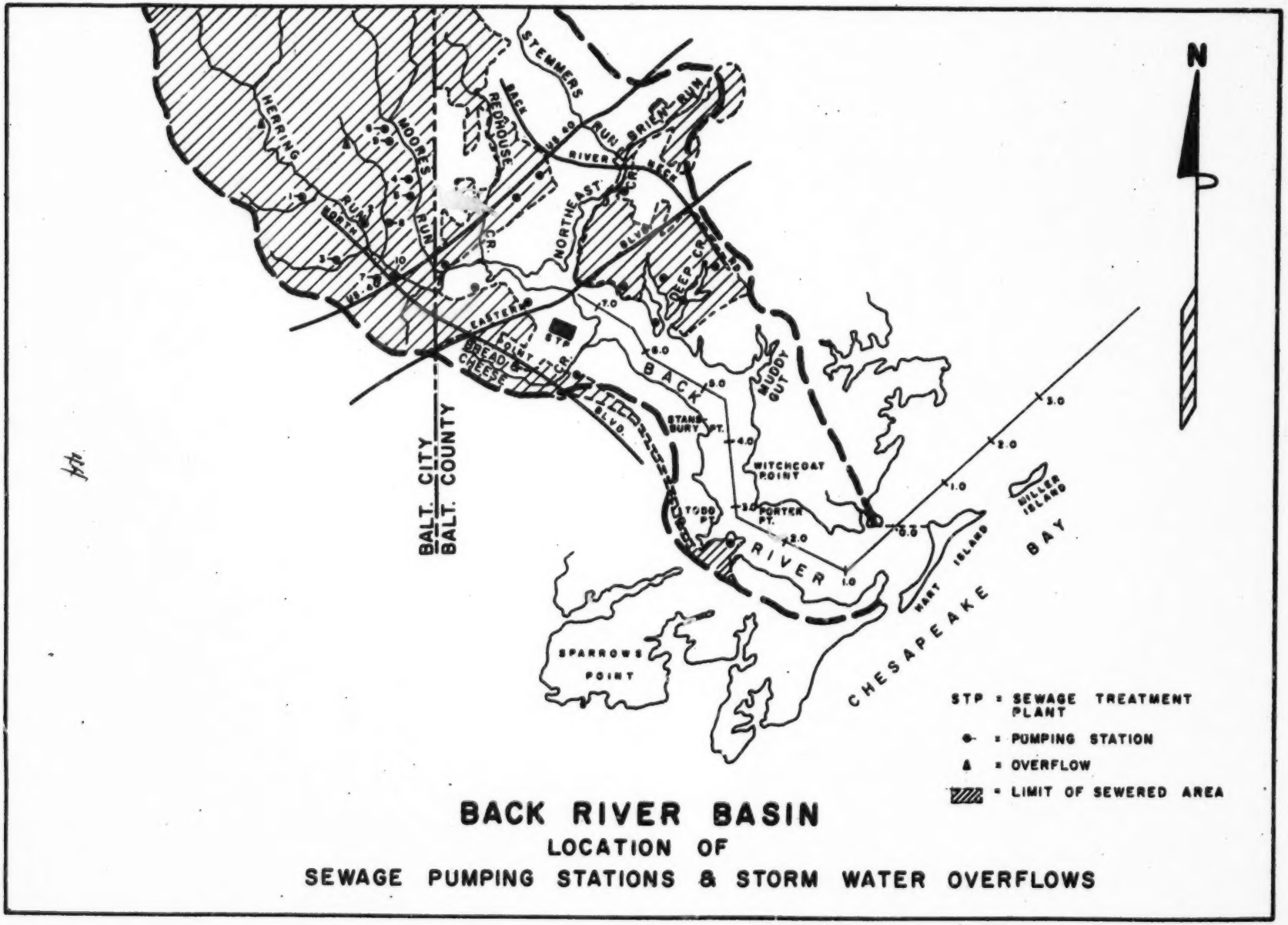
FIGURE 3


STA. B1 GREENMARSH POINT
STA B1A STP EFFLUENT
STA. B1B COX POINT
STA. B2 BELOW WALNUT POINT
STA. B3 PORTER POINT
STA. B4 CLAYBANK POINT
STA. B5 DRUM POINT
STA. B6 WELLS POINT - MILLERS ISLAND
STA. B7 NE of MILLERS ISLAND
COLIFORM BACTERIA, GEOMETRIC MEAN DENSITY MPN/100 ml
100,000
10,000
1,000
100
10
0
MPN - 95% OF TIME
GEOMETRIC MEAN
MPN - 5% OF TIME
8.0 7.0 6.0 5.0 4.0 3.0 2.0 1.0 0.0 1.0 2.0 3.0 4.0
MILES ABOVE MOUTH OF BACK RIVER
MILES INTO CHESAPEAKE BAY

BACK RIVER ESTUARY

PROFILE OF RIVER COLIFORMS, GEOMETRIC MEANS, STP BOAT STATIONS

FIGURE 6

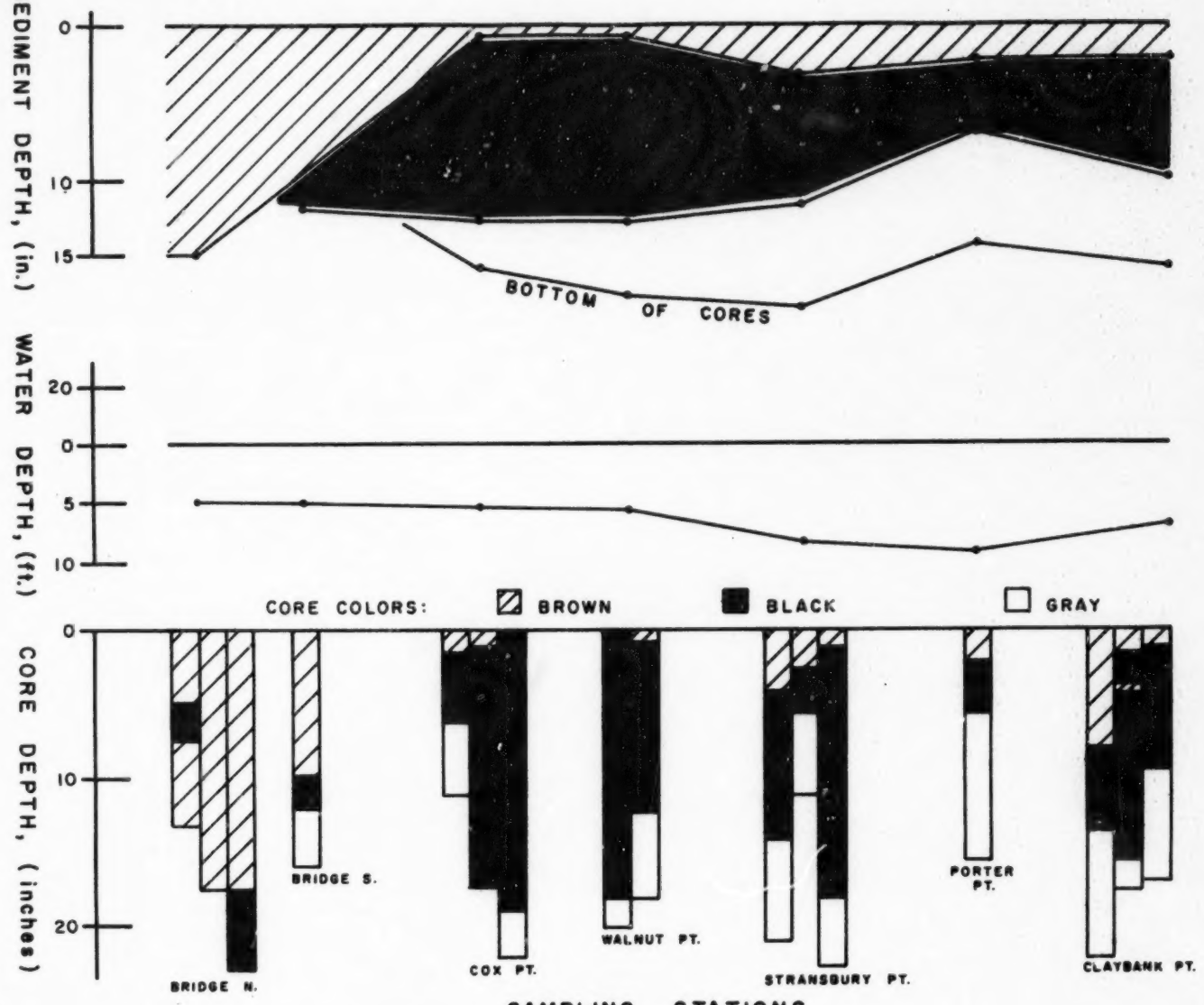


BACK RIVER BASIN

LOCATION OF

SEWAGE PUMPING STATIONS & STORM WATER OVERFLOWS

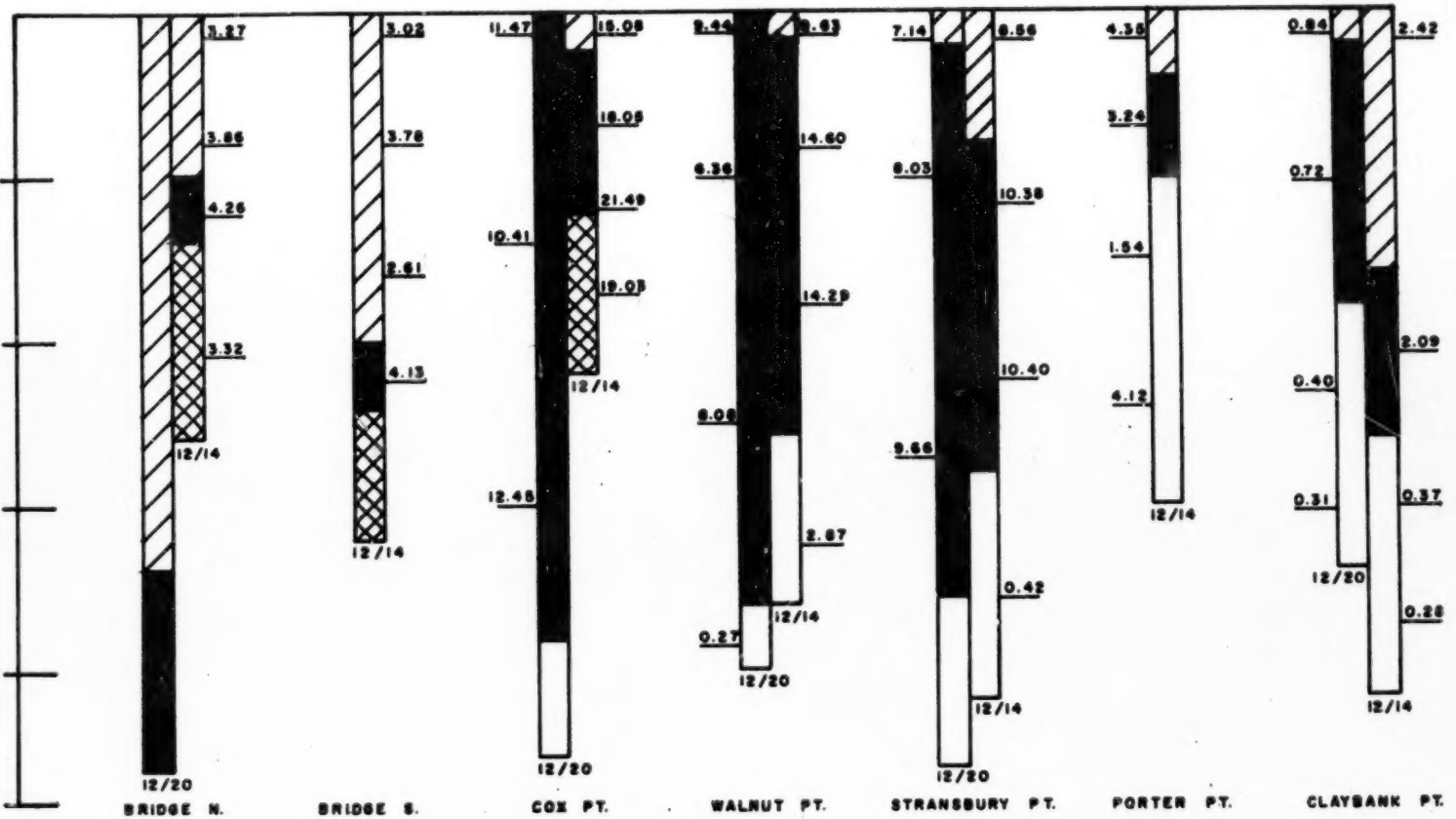
FIGURE 7



BACK RIVER ESTUARY

SEDIMENT PROFILE

FIGURE 8



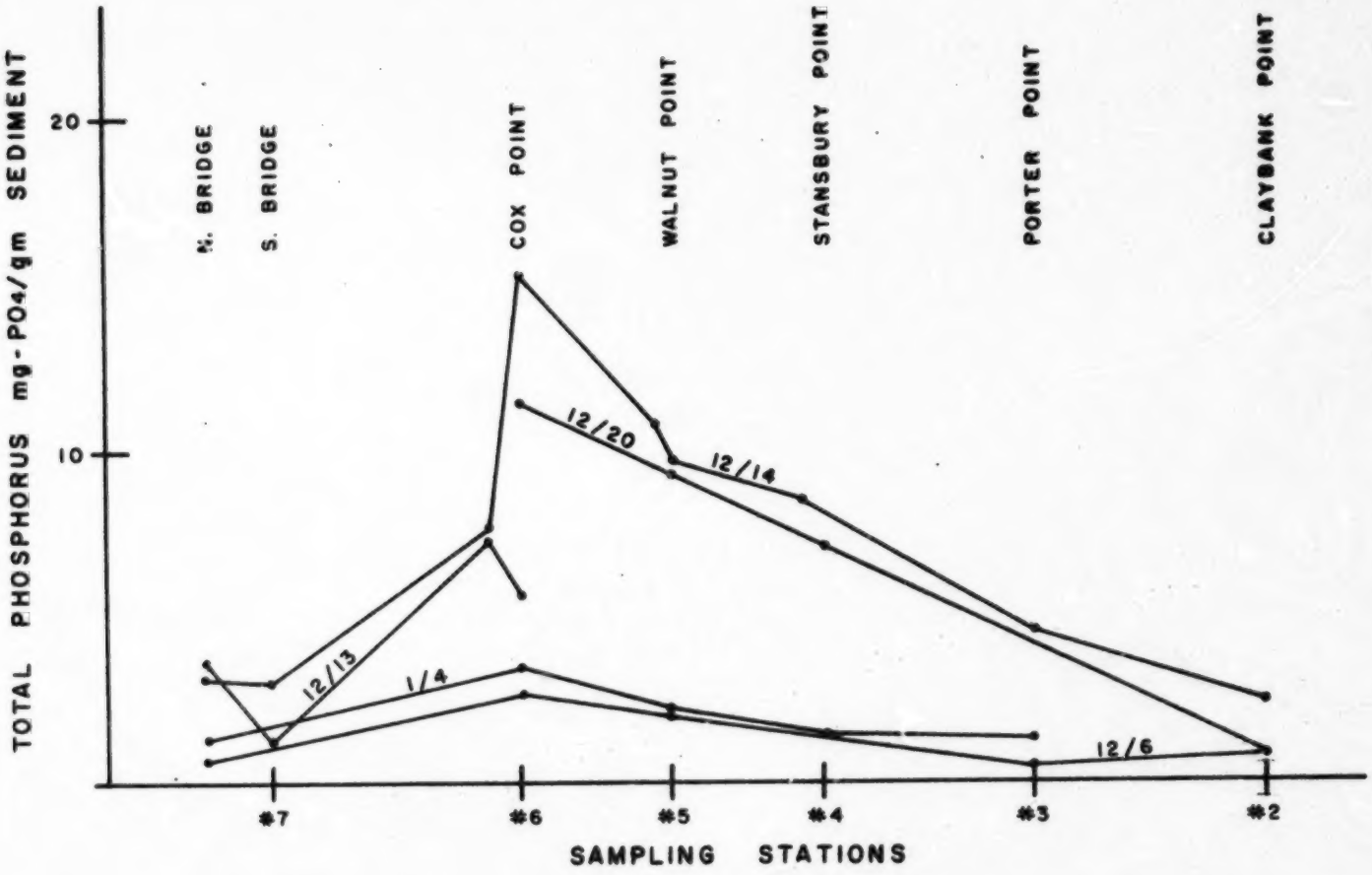
BACK RIVER ESTUARY

TOTAL PHOSPHORUS IN BOTTOM CORE SAMPLES

(EXPRESSED IN mg PO_4 PER GRAM DRY WEIGHT OF SEDIMENT)

CORE COLORS: ▨ BROWN ■ BLACK □ GRAY ▩ MIX. of BROWN & BLACK

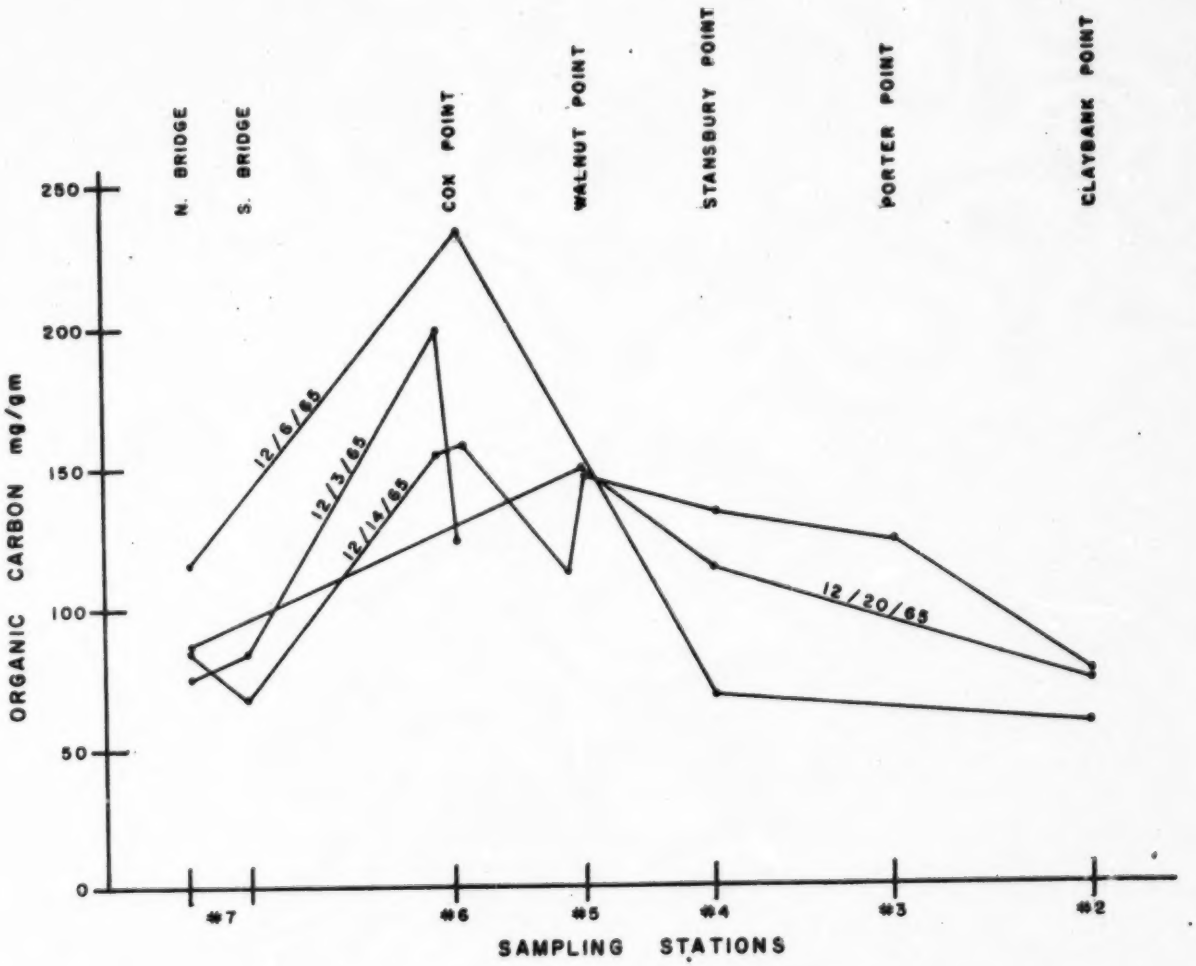
FIGURE 6



BACK RIVER ESTUARY

TOTAL PHOSPHORUS CONCENTRATIONS IN TOP 5cm OF SEDIMENTS

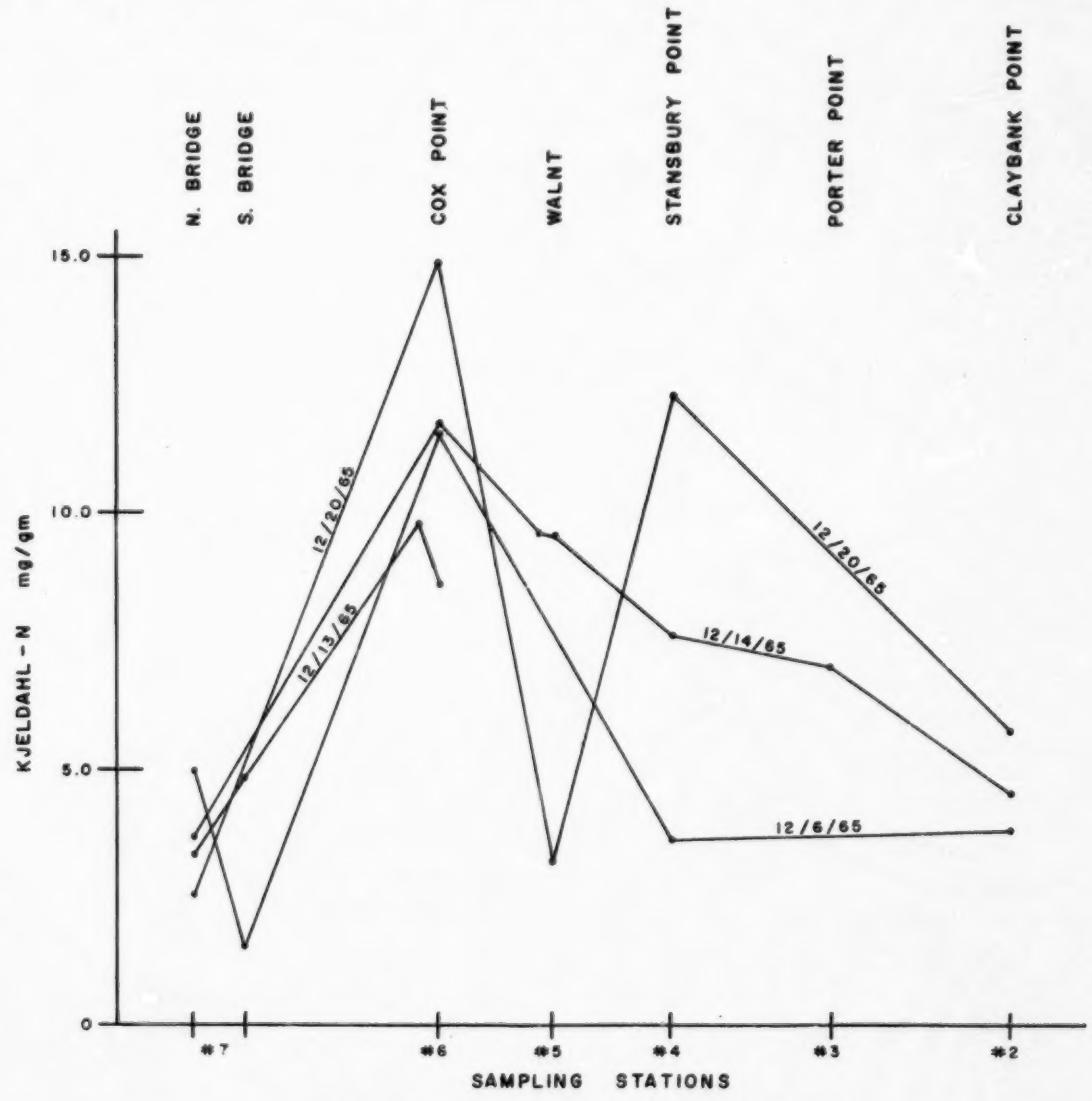
FIGURE 10



BACK RIVER ESTUARY

ORGANIC CARBON IN TOP 5cm OF SEDIMENTS

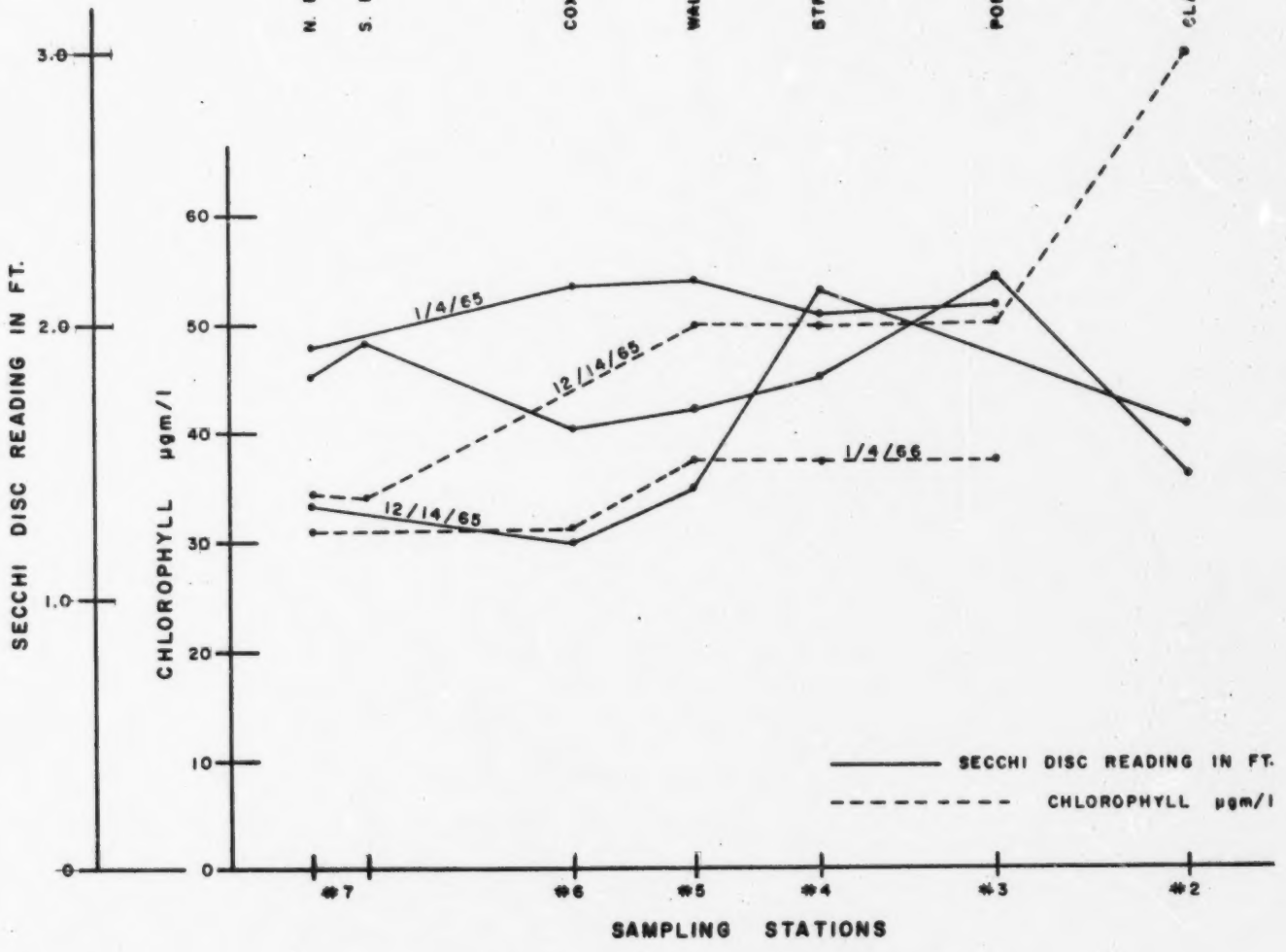
FIGURE 11



BACK RIVER ESTUARY

KJELDAHL NITROGEN IN TOP 5cm OF SEDIMENTS

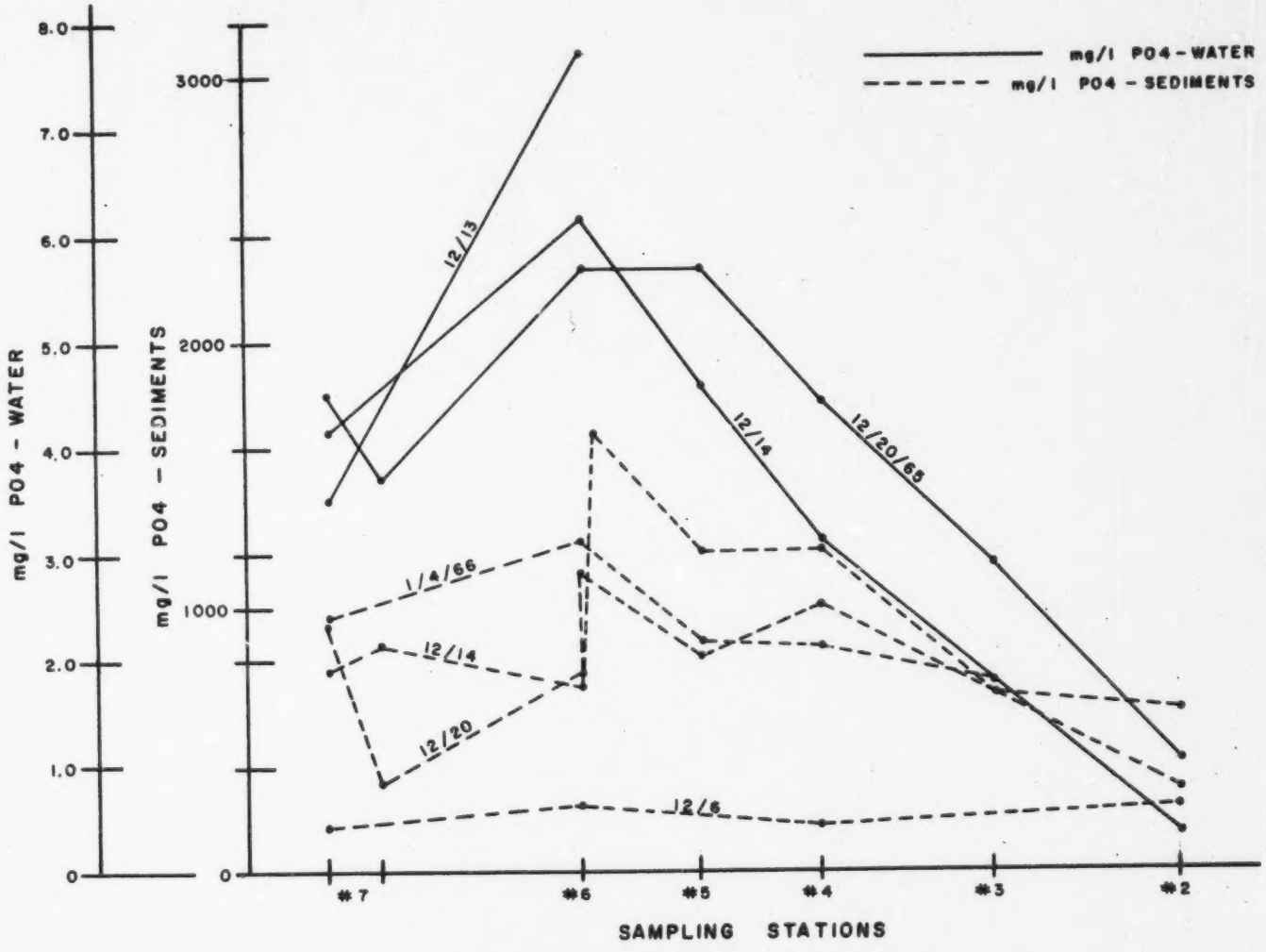
FIGURE 12



BACK RIVER ESTUARY

CHLOROPHYLL CONTENT & SECCHI DISC EXTINCTION READINGS

FIGURE 13.



BACK RIVER ESTUARY

TOTAL PHOSPHORUS IN WATER & IN TOP 5cm OF SEDIMENTS

FIGURE 14

APPENDIX I

ANALYTICAL PROCEDURES

BACTERIOLOGICAL

1. Chesapeake Field Station

(a) All multiple-tube analyses were performed using five tubes per serial dilution. Samples for Most Probable Number of the chlorinated effluent of the sewage treatment plant were collected in bottles containing sodium thiosulfite which reacts with the chlorine to prevent a nontypical disinfection contact time between collection and inoculation.

(b) Method for Coliform Group. Analyses were performed according to Standard Methods*, using the fermentation tube technique. All presumptive tubes were incubated for 48 hours and those positive submitted to the confirmed test, using brilliant green lactose bile broth. MPN's were taken from positive confirmed tubes.

(c) Method for Fecal Coliform Group. Analyses were performed according to Standard Methods, using EC medium at 44.5° C. All tubes were incubated 48 hours.

(d) Method for Fecal Streptococcus. Analyses were performed according to Standard Methods, using the azide broth presumptives and ethyl violet aside broth confirming media. Both presumptive and confirmed tests were performed. All tubes were incubated for 48 hours.

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* Standard Methods for the Examination of Water, Sewage, and Industrial Wastes, APHA.

2. Maryland State Department of Health

Certain samples collected by the Health Departments of Baltimore City and Baltimore County were analyzed for coliform and fecal coliform by the Maryland State Department of Health laboratory as a service to the Chesapeake Field Station. The procedures were virtually the same as CFS procedures, and data have been treated identically with CFS data.

3. Baltimore City

Bacteriological samples collected by Baltimore Back River STP over the period 1962-1965 were analyzed by the Baltimore City Health Department laboratory. The MPN's were based on presumptive tubes, using three tubes per serial dilution. Samples taken from chlorinated plant effluent were analyzed both with and without addition of thiosulfite.

CHEMICAL AND PHYSICAL*

* Standard Methods for the Examination of Water, Sewage, and Industrial Wastes, APHA.

APPENDIX II

RESULTS OF BACTERIAL ANALYSES

TABLE A-1

CFS BACK RIVER SURVEY, November 1-12, 1965
Coliform Densities MPN/100 ml

Date	STATIONS ON MAIN ESTUARY											
	1	2	3	4	5a	5b	5c	6a	6b	6c	7	8
11- 1	20	50	70	170	320	790	490	3,480	490	340	3,300	3,300
				490	330	790	270	490	460	490	9,400	4,900
11- 2	80	<20	110	330	1,300	800	200	500	4,600	3,300	3,480	5,420
				130	<200	800	200	13,000	800	1,100	4,900	16,000
11- 3	20	490	790	130	800	<200	200	1,300	<200	500	200	490
	4 - 6.8	23	41-230	330	500	500	200	200	<200	500	800	700
									460			
11- 4	20	20	130	220	800	700	500	160,000	1,300	1,300	17,200	9,200
				110	200	500	200	13,000	3,300	54,200	54,200	16,000
11- 5	<20	110	80	130	14,100	7,900	500	1,300	2,200	2,300	2,200	5,420
				80	1,100	1,700	200	3,300	3,300	3,300	7,900	1,720
11- 8	<20	490	9,200	9,200	9,200	16,000	9,200	13,000	9,600	24,000	24,000	14,000
				3,480	9,200	3,480	16,000	800	2,300	7,000	3,300	2,300
11- 9	20	110	330	1,300	2,400	1,090	940	4,900	500	2,100	2,300	2,300
				1,720	3,480	1,300	460	2,200	500	1,100	13,000	4,900
11-10	<20	70	170	790	790	1,300	490		200	500	3,300	3,300
	23	79	330	330	790	330	790	1,400	200	800	3,300	4,600
									1,400			
11-11	<20	<20	170	220	310	220	330	17,200	1,700	800	500	1,100
				700	9,200	>16,000	3,480	200	4,900	1,100	7,900	2,200
11-12	<20	<20	130	170	1,720	330	490	1,700	2,200	1,100	1,700	800
				1,700	1,090	2,400	330	1,300	500	2,200	3,300	2,300

TABLE A-1 (Continued)

CFS BACK RIVER SURVEY, November 1-12, 1965
Coliform Densities MPN/100 ml

Date	Stations on Tidal Tributaries A	B	C	D	Stations on Free-flowing Tributaries E	F	G	H	I	STP J
11- 1	<20		1,300	13,000	33,000	1,400	130,000	49,000	23,000	200
	4,900		3,300		24,000	<200				<200
11- 2	<200	800	2,400	500	23,000	1,100	49,000	14,000	17,000	500
	200	700	5,420				34,800	<200		<200
11- 3	200	400	170	800	49,000	1,100	130,000	11,000	7,900	<200
	1,700	1,300			1,750				5,420	130
11- 4	20	17,500	5,420	4,900	13,000	330	79,000	110,000	3,300	490
	1,100	500	16,000			<200	34,800			2,400
11- 5	220	700	2,400	4,900	7,000	330	110,000	33,000	7,000	9,400
	800	3,400	790					54,200	3,300	80
11- 8	9,200	4,600	14,000	7,000	7,900	14,000	49,000	79,000	280,000	<20
	1,720	24,000	4,900		24,000	7,900				110
11- 9	330	1,720	7,900	16,000	79,000	790	1,700,000	22,000	33,000	1,090
	1,090	5,420	4,900				>160,000	92,000		1,300
11-10	330	330	1,700	2,210	130,000	2,300	330,000	4,900	7,900	80
	490	2,400	7,200		34,800				4,600	<20
11-11	700	490	800	2,400		330	34,500			9,200
	940	1,300	2,100							<20
11-12	330	3,480	3,300	5,420	11,000	2,300	330,000	79,000	22,000	<20
	330	1,720	2,300					430		130

TABLE A-2

CFS BACK RIVER SURVEY, November 1-12, 1965
Fecal Coliform Densities MPN/100 ml

Date	Stations on Main Estuary											
	1	2	3	4	5a	5b	5c	6a	6b	6c	7	8
11- 1	20	20	20	80	110	330	230	130	50	40	<200	<200
				80	170	130	<20	40	80	<20	900	1,100
11- 2	<20	<20	<20	70	1,300	<200	200	200	<200	<200	<20	20
				<20	<200	<200	<200	2,300	200	<200	800	230
11- 3	20	170	490	50	800	<200	200	1,300	<200	700	1,300	340
	<2	13	17-33	110	<200	200	200	<200	<200	200	200	1,720
									31			
11- 4	20	<20	130	220	500	700	500	160,000	1,300	1,300	10,900	3,480
				170	500	800	500	13,000	2,300			
11- 5	<20	<20	50	50	6,300	4,900	200	2,300	1,100	1,300	<20	700
				20	<200	700	<200	1,400	3,300	3,300	4,900	1,300
11- 8	<20	130	40	60	50	50	5,420	3,300	1,300	1.400	2,300	800
				90	120	170	3,480	800	500	3,300	1,300	500
11- 9	<20	40	170	490	490	460	460	800	<200	200	200	800
				210	490	490	790	800	200	800	2,300	1,300
11-10	<20	<20	<20	<20	< 20	<20	50		<200	<200	<200	<200
	< 1.8	2	33	<20	< 20	<20	<20	200	<200	<200	200	<200
									79			
11-11	<20	<20	50	110	130	70	50	13,000	1,700	200	200	500
				20	3,480	5,420	1,720	<200	1,700	200	800	<200
11-12	<20	<20	<20	<20	80	<20	50	200	200	<200	800	500
				50	130	70	40	200	500	900	<200	800

TABLE A-2 (Continued)

CFS BACK RIVER SURVEY, November 1-12, 1965
Fecal Coliform Densities MPN/100 ml

Date	Stations on Tidal Tributaries A	B	C	D	Stations on Free-flowing Tributaries E	F	G	H	I	STP J
11- 1	20		<200	2,100	2,200	640	49,000	3,300	1,300	<200
	900		1,700		3,300	<200				<200
11- 2	<200	<200	<20	<200	13,000	70	4,900	3,300	790	200
	<200	200	230				<200	<200		<200
11- 3	800	<200	270	<200	1,700	170	7,900	2,800	1,300	<200
	500	500			460				5,420	50
11- 4	20	9,400	5,420	2,400	2,800	170	4,600	17,000	280	490
	1,100	1,300				<200	160,000			2,400
11- 5	130	200	1,300	700	790	80	110,000	7,900	2,200	6,300
	800	1,200	790					4,100	3,300	20
11- 8	50	790	800	20	3,300	790	2,200	2,800	3,300	<20
	60	2,780	200		500	50				<20
11- 9	330	110	1,700	940	490	80	4,300	1,300	1,700	170
	2,300	3,480	800				34,500	10,900		220
11-10	<20	20	<200	130	790	790	33,000	3,300	790	<20
	<20	130	<200		<200				<20	<20
11-11	130	490	200	170		130	160,000			790
	130	330	800							<20
11-12	20	70	500	1,300	310	80	22,000	13,000	2,800	<20
	230	230	200					430		50

TABLE A-3

CFS BACK RIVER SURVEY, November 1-12, 1965
Fecal Streptococcus Densities MPN/100 ml

	Stations on Main Estuary											
Date	1	2	3	4	5a	5b	5c	6a	6b	6c	7	8
11- 1	<20	<20	<20	<20	<20	20	40	<20	80	50	20	50
				20	50	130	50	270	80	40	60	60
11- 2	<20	<20	<20	50	20	<20	20	460	230	20	170	110
				20	<20	<20	<20	<20	<20	20	50	110
11- 3	<20	<20	<20	<20	<20	<20	<20	<20	20	<20	<20	50
				<20	<20	<20	<20	<20	<20	50	<20	40
11- 4	<20	<20	<20	20	<20	20	70	130	50	<20	90	130
				<20	20	<20	20	50	<20	70	20	40
11- 5	20	<20	<20	<20	20	<20	<20	20	<20	<20	20	50
				<20	<20	<20	<20	80	50	<20	<20	50
11- 8	<20	<20	<20	<20	20	<20	20	<20	50	110	20	20
				<20	170	20	20	<20	<20	70	330	170
11- 9	170	210	490	120	2,530	490	330	3,480	490	2,400	1,300	1,090
				<20	50	20	170	190	60	80	140	110
11-10	<20	<20	<20	<20	<20	20	<20	<20	20	<20	130	20
				<20	<20	<20	<20	500	230	230	330	140
11-11	<20	<20	<20	<20	40	20	20	40	20	<20	<20	<20
				<20	<20	20	20	<20	<20	20	110	20
11-12	<20	<20	<20	<20	<20	20	<20	<20	40	<20	50	80
				<20	20	<20	<20	<20	20	20	20	50

TABLE A-3 (Continued)

CFS BACK RIVER SURVEY, November 1-12, 1965
Fecal Streptococcus Densities MPN/100 ml

Date	Stations on Tidal Tributaries A	B	C	D	Stations on Free-flowing Tributaries E	F	G	H	I	STP J
11- 1	<20		20	40						<20
	20				20	<20				<20
11- 2	<20	330	130	20						<20
	<20	<20	20				80	<20		<20
11- 3	<20	20	<20	<20						<20
	<20	110			80				20	<20
11- 4	<20	90	80	70						<20
	80	80	50			<20	80			<20
11- 5	20	<20	<20	20						<20
	<20	<20	20					1,700	20	<20
11- 8	<20	80	<20	120						<20
	<20	460	330		1,090	90				40
11- 9	330	16,000	1,300	<20						1,300
	20	<20	50				470	80		<20
11-10	<20	<20	20	<20						<20
	<20	80	<20		130				80	<20
11-11	20	20	20	<20		<20	170			<20
	<20	140	110							<20
11-12	<20	20	20	50						<20
	20	80	<20					110		<20

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TABLE A-4

BACK RIVER, 1962-1965
COLIFORM DENSITIES MPN/100 ml
AT BALTIMORE STP BOAT STATIONS

Station	B-1	B-1-A	B-1-B	B-2	B-3	B-4	B-5	B-6	B-7
Date (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1962)									
June 8	430	230	230	230	43	43	93	23	23
July 5	430	4,300	230	7.3	9.1	43	43	3.6	9.1
Aug. 16	430	--	2,300	15	23	150	23	3.6	20
Sept. 21	4,300	4,300	4,300	230	230	43	93	43	--
(1963)									
June 20	430	230	4,300	230	23	230	2,100	430	43
July 18	2,300	110,000	110,000	230	43	23	930	430	93
Aug. 22	23,000	7.2	2,300	930	43	23	<3	3	3.6
(1964)									
June 18	7,500	4,300	460,000	75	93	9.1	7.3	23	3.6
July 23	430	930	7.3	43	150	930	150	150	2,800
Aug. 13	2,300	930	15	43	240	43	3.6	240	43
Sept. 17	430	1,100,000	150	93	23	93	43	3.6	<3
(1965)									
June 16	93	930	230	43	23	43	23	0.0	9.1
July 21	24,000	240	460,000	9.1	23	3.6	9.1	0.0	0.0
Aug. 16	1,500	9,300	9,300	2,400	75	15	9.1	9.1	3.6

APPENDIX III

STATISTICAL PROCEDURES USED FOR ANALYSIS OF BACTERIOLOGICAL DATA

The basis for the statistical manipulations performed on the bacteriological data is the log-normal distribution. This best describes the variability of bacterial numbers in natural waters. The log-normal distribution applies where the logarithms of a set of data rather than the data themselves are normally distributed. The appropriate measure of central tendency of such a distribution is the log mean or geometric mean which coincides with the median or the value exceeded 50 per cent of the time.

As stated previously, the serial tube dilution method of analysis was used to estimate bacterial numbers (MPN) in each sample collected. The result of a single such test is actually just a statistical estimate of the true number of bacteria present. If a series of such tests were performed on a single sample, these results would also be distributed in a log-normal fashion due to the statistical nature of the test itself. The best estimate of the true bacterial density of the sample would be the mean of the logarithms of the results or the geometric mean. The variability of the results obtained using this method of analysis depends upon the number of portions or tubes used for each sample dilution. The greater the number of tubes, the less will be the variability of the test results.

Since the analytical procedure itself has a predictable variability, it is necessary that this be eliminated from the test results before they are subjected to further statistical analysis.

The procedure used to accomplish this is as follows:

1. The test results of samples from each station are plotted on log-probability paper as in Figure A-1 and a straight line drawn through the points.

2. The geometric mean is found at the intersection of the plotted line and the 50 per cent occurrence line (i.e., MPN of 1000/100 ml).

3. The standard deviation of the log-normal distribution is obtained from the plot. This may be done by subtracting the logarithm of the value (280) found at the intersection of the plotted line and the -1σ vertical from the logarithm of the geometric mean (1000), i.e., log 1000 - log 280 = 0.55.

4. This standard deviation is then corrected for the variability of the test procedure by reducing it by an appropriate factor depending upon the number of tubes used, i.e., 0.32 for three portions and 0.25 for five portions*. Since five portions were used in these tests, the corrected standard deviation in the example is 0.55 - 0.25, or 0.30.

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* Velz, C. J.

This information may now be used to calculate the coliform density that would occur with any given frequency. The value exceeded five per cent of the time, for example, would be the mean density plus 1.65 times the corrected standard deviation. In this example,

$$(1.65 \times 0.30) + \log 1000 = \log \left(\begin{matrix}\text{Value exceeded} \\ 5\% \text{ of the time}\end{matrix}\right)$$

the value exceeded five per cent of the time is found to be 3120.

The term, mean coliform density, is usually presumed to refer to the geometric mean, since the variation of coliform bacteria in natural waters is best described by a log-normal distribution. However, it is sometimes desired to know the arithmetic mean density. This may be determined accurately only by calculation using the geometric mean density and standard deviation as determined from Figure A-1. This calculation has been simplified to a ratio (R) of the arithmetic mean to the geometric mean. This ratio depends upon the magnitude of the uncorrected standard deviation as shown in the table below:

σ_{log}	R	σ_{log}	R
0.00	1.00	1.04	17.7
0.30	1.27	1.08	21.9
0.48	1.83	1.12	26.8
0.60	2.61	1.15	32.5
0.70	3.65	1.18	39.1
0.78	4.98	1.20	46.7
0.85	6.65	1.23	55.3
0.90	8.67	1.26	65.1
0.96	11.2	1.28	76.2
1.00	14.2	1.30	88.8

Thus, for the data in Figure A-1 where σ_{log} is 0.55, R may be estimated for the table as being 2.29. This value must also be corrected for the variability of the MPN test by multiplying it by a factor of 0.85 for a 5-tube test or 0.76 for a 3-tube test. In this example, five tubes were used, and R has a corrected value of 1.95. Thus, the arithmetic mean is found to be almost twice the geometric mean, or 1950.

The arithmetic mean will always be larger than the geometric mean due to the nature of the log-normally distributed data which is skewed toward the higher values. As shown in the table above, the discrepancy rapidly becomes very large as the variability of the data (or σ_{log}) increases.

APPENDIX IV

REGULATIONS OF THE MARYLAND STATE BOARD OF HEALTH AND MENTAL HYGIENE GOVERNING PUBLIC SWIMMING POOLS AND BATHING BEACHES, REGULATION 43 L 04, APRIL 26, 1951, SANITARY QUALITY OF WATER, ETC. (part)

Under authority conferred by Section 2 of Article 43 of the Annotated Code of Maryland . . .

"The bacterial quality of water of natural bathing beaches is acceptable when the water shows an average 'most probable number' (MPN) of coliform bacteria not in excess of 1,000 per 100 milliliters in any one month during the bathing season, provided a sanitary survey discloses no immediate danger from harmful pollution. The presence of such pollution shall be determined from the findings of sanitary surveys made by the State Board of Health and Mental Hygiene.

"The right is reserved to close any swimming pool or bathing beach because of continued failure to meet the above standards."

APPENDIX V

RESEARCH PROJECT OF MR. JACK GRAVES

Mr. Graves of the Johns Hopkins School of Public Health, as his Master's thesis, conducted tests in both the Back River and Middle River to try to determine why milfoil, which is abundant in the Middle River, does not grow in the Back River. In fact, very few if any bottom aquatic plants can be found in the Back River. Since there are numerous opportunities for the milfoil plant to have been introduced to Back River, and since its environment is very similar to that of the Middle River, there would appear to be some inhibitory factor present in the Back River.

For his investigation Mr. Graves removed milfoil plants from the Middle River, washed their roots, and replaced half of them in boxes of Middle River bottom sediments and half of them in boxes of Back River bottom sediments. Boxes of each type were placed in the Back River and in the Middle River. Within three weeks the plants in the boxes in the Back River were essentially dead. After the same period of time, the plants in boxes placed in the Middle River were found to be flourishing, regardless of the source of the sediment in which they were rooted.